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# A MODEL FOR DETERMINING THE AVERAGE SERVICE LIFE OF EQUIPMENT *

By

Roger B. Orensteen
International Business Machines Corporation

Life estimates are used in various fields, including depreciation accounting, engineering valuation, capital budgeting, and engineering economy studies. Several sets of data on life estimates are available. For estimating depreciation charges for income tax purposes, the U. S. Internal Revenue Service has issued Bulletin F,[1] which contains a list of "average useful lives". The most complete list of service lives prepared for purposes of engineering valuation is to be found in Marston and Agg's "Engineering Valuation",[2] which gives estimates for about 1600 items together with the source of the estimate for each.

> This table has been computed from data obtained from many sources and represents the practice of valuation engineers, regulatory commissions, and similar authorities, rather than the actual average service life as determined from mortality data on the kind of property listed.[3]

* Presented at the Fifth Annual Meeting of the Operations Research Society of America, Philadelphia, Pa., May 10, 1957. The study was conducted under a MAPI Fellowship at the National Center of Education and Research in Equipment Policy, Illinois Institute of Technology, Chicago, Ill. The author wishes to acknowledge the assistance rendered by Dr. G. J. Matchett, who acted as research advisor.

[1] Income Tax Depreciation and Obsolescence, Estimated Useful Lives and Depreciation Rates, Bulletin F (revised January 1942). Government Printing Office, Washington, D. C., 1942.

[2] A. Marston and T. R. Agg: Engineering Valuation, 1st Edition, pp. 497-514. McGraw-Hill Book Co., New York, 1936.

[3] Ibid., p. 497.

Although authorities in the field of engineering valuation now consider Bulletin F to be superior to the data of Marston and Agg, they are still not satisfied that

> ..... Bulletin F is not also largely a compilation of opinion and practice rather than of service lives calculated from retirement experience.[4]

Still, they offer no empirical evidence that Bulletin F service lives are significantly in error.

The only published service life data which are known to be the result of empirical study are contained in the 176 mortality studies of physical property by Kurtz and Winfrey.[5] Unfortunately this listing includes a miscellany of equipment classes and contains little information on metalworking equipment. Furthermore, if the experience of Kurtz and Winfrey is indicative of the time and effort it takes to obtain service lives by compiling mortality data, there is little hope we shall ever have, from their approach, enough data for general use.

Although for use in economy studies there has been some controversy over just what data life estimates should be based upon, average service lives are usually not recommended for this purpose. Average service life is derived from actual retirement practice. If there is a question as to whether actual practice is really

[4] Anson Marston, R. Winfrey and Jean C. Hempstead: Engineering Valuation and Depreciation, pp. 173-174. McGraw-Hill Book Co., Inc., New York, 1953.

[5] E. B. Kurtz and R. Winfrey: Statistical Analysis of Industrial Property Retirements. Bulletin 125, Iowa Engineering Experiment Station, Ames, Iowa, 1935.

economic, then it should not be incorporated in a study which is to determine the economics of retirement. Moreover, average service lives represent the total life through many ownerships, and the first owner is obviously going to be interested in the equipment only while it is in his possession. Although there is an absence of evidence that retirement practice does not closely approximate the ideal, there has always been a feeling among engineering economists and equipment manufacturers that retirements are typically deferred beyond the most economic point.

While average service lives are thus of questionable value in connection with life estimates, they may be employed usefully in the estimation of salvage values in economy studies.[6] Indeed, it is for this purpose that this research is pursued; but it may have useful by-products in other areas as well. In any event it is evident that there is a need for a new and comprehensive approach in arriving at average service lives, because of the recognized deficiencies in approaches currently used and in existing tables of such data.

Traditional approaches to average service life determination attempt to obtain a mortality-frequency curve for a class of equipment. This curve shows the fraction of an original group of machines which are retired at various points in time after their initial installation together. The average age at retirement

[6] Roger B. Orensteen: Estimating Salvage Values in MAPI Equipment Analysis. Unpublished Ph.D. Thesis, Illinois Institute of Technology, Chicago, 1956.

from productive service is then easily determined. Needless to say, the task of following a group over such a long period of time, isolating the influence of outside disturbances all this while, is difficult and complicated.

The approach taken in this paper is through information gathered on survivors rather than on retired equipment. Such information is obtainable in the form of equipment inventories. What is the age-distribution of equipment in the inventory? What is the composition of the inventory like? What has been the growth pattern of the inventory? If we had answers to these questions and knew, in addition, the part which the mortality-frequency distribution plays in determining the age-distribution of surviving equipment, perhaps we could forego elaborate mortality studies of the traditional kind.

## CHARACTERISTICS OF EQUIPMENT INVENTORY

Before going into a mathematical treatment of the relationship between mortality characteristics and equipment age-inventory, some general remarks are in order on the subject of equipment inventory. We can obtain an age-distribution of existing equipment. The factors which determine the age-distribution are: (1) growth, or more generally, change in the total number of machines; (2) changes in the composition of the group, where the group is made up of several dissimilar sub-classifications; (3) mortality-frequency distribution of machines, that is, the pattern which governs their retirement from use.

It is not difficult to envisage the influence of changes in the total number of machines in use. If, for example, the total

number is growing, we can expect a heavier distribution of machines at the younger ages than if the total were constant. If a particular type-classification is made up of a large number of machines in different uses, we can expect that any changes in this composition will also have an effect. If, for example, in a particular use, average service life is relatively short, then a growing predominance of equipment in this use would obviously weight the age-character of the type-classification in a corresponding manner. In our mathematical treatment we shall assume that the groups dealt with are either reasonably homogeneous or contain unvarying proportions of equipment in different uses.

We can also expect that retirement practice will influence the age-distribution of surviving equipment. The shorter the average service life of the equipment, the heavier is the age-distribution of equipment at younger ages. The shape of the retirement distribution will also have an influence. Retirement distributions may be skewed heavily toward retirement ages beyond the average service life, and this will clearly influence the age-distribution of equipment in existence at any moment.

Our model must make possible the conversion of age-distributions of equipment in use to average service lives. This means that the model must incorporate the influence of growth, composition, and mortality-frequency distribution on inventory age-distribution. Then we can work backwards to the average service life, given the age-distribution, growth pattern, and composition. The model which we will discuss is based on certain assumptions with reference to these factors. These assumptions must be understood

if the limitations as well as the benefits of this approach are to be appreciated.

## THE MODEL OF EQUIPMENT INVENTORY

### Assumptions of the Model

The model has been worked out to permit almost any shape of mortality-frequency, but in particular the type which one usually encounters in mortality studies of physical property. But one stipulation is made, namely, that each group of machines added to the total stock will be subject to the same retirement pattern. In other words, the units in this new group will always have the same mortality-frequency distribution as the original group.

The model has been worked out for two cases, the first where there is a constant total stock of equipment, and the second where there is a uniform rate of growth in the total stock. And equipment groups are assumed to have type-composition and use-composition which do not change significantly over time. The mortality-frequency distribution is applicable to such groups.

The mortality-frequency curve is assumed to be of the Iowa Type $S_3$. As mentioned above, studies were published on 176 different industrial property groups, resulting from research by the Iowa Engineering Experimental Station, Iowa State College. A classification system for mortality-frequency curves was devised. It was found, after calculating an average service life from the mortality-frequency curve and stating the age in per cent of this value, that the resulting mortality curves could be classified into 18 basic groups; seven are symmetrical, differing from each other in degree of dispersion around the average, six are skewed

to the left, and five are skewed to the right (differing in both skewness and dispersion in such a manner that greater skewness is associated with greater dispersion).

George Terborgh studied the 176 published curves and found that a weighted average of the 18 distributions (weighted by number of times each is used in fitting the 176 empirical distributions) is itself a curve resembling the Iowa Type $S_3$.[7] It is noteworthy that this is the middle classification in the Iowa System, the third in the symmetrical group. If the 176 empirical curves prepared at the Iowa Experimental Station are at all a representative sample of physical property, one can consider using the Iowa Type $S_3$ curve for a particular property group whose curve shape is unknown; or for a group which is, itself, a composite of many individual groups.

Average Service Life

We shall begin our mathematical treatment of equipment inventory with the mortality-frequency distribution and average service life. A mortality-frequency distribution shows the fraction of the total, in a group of similar machines installed at the same time, retired at various ages. Denote this distribution by f(x), where x is the attained age. The average service life L is the average age at retirement, the first moment of f(x):

$$L = \int_0^N xf(x)\,dx \qquad (1)$$

[7] George Terborgh: Realistic Depreciation Policy, p. 174. Machinery and Allied Products Institute, Washington, D.C., 1954.

The Life Table

Another distribution, the life table as it is called, can be obtained from the mortality distribution. The life table shows the fraction of the total number of machines which have survived to the given age. Calling this distribution M(x),

$$M(x) = \int_{X}^{N} f(x)\, dx \qquad (2)$$

For an insight into the nature of the functions being discussed, we refer to empirical studies of equipment mortality. The mortality distribution and life table for the Iowa Type $S_3$ data are shown in Figure 1. When the ages are expressed as percentages of the average service life, the curves are called "generalized". It is in this generalized form that they will be most useful.

Age Distribution of Surviving Equipment

The mortality-frequency distribution shows the retirement characteristics of a group of similar machines from the time of installation to the demise of the last unit. The fraction of the total machines remaining at any time is given by the life table.

Now let us consider what will happen if instead of allowing the number of machines we use to decline as machines are retired, we install new machines in such a way as to make the total number of machines satisfy some requirement. We consider two cases. First, assume that instead of allowing the total to fall off in the manner of the life table, the total is kept stable at the original amount. This is done by continuous replacement of the retired items with like items, subject to the same mortality distribution. Or, second, assume that the total number is increased,

say, by a constant percentage amount each year. Since our interest is in machine inventory, it will be useful to have expressions for the age-distribution of surviving equipment under these various assumptions. It will be especially valuable to be able to relate the average survivor age, as determined from the age-distribution of surviving plant, to the average service life as defined above.

We are fortunate to find in the literature of renewal theory certain theorems which have been developed in the analysis of depreciation charges and plant accounts.[8]

> The age distribution of surviving plant tends toward the age distribution of the life table
>
> $$M(x)/L \qquad (3)$$
>
> with the passage of time, if the plant is maintained at a constant level.
>
> Under uniform growth of plant at rate k, the age distribution of plant balance tends toward the function
>
> $$e^{-kx} M(x)/P(k) \qquad (4)$$
>
> with the passage of time, where P(k) is defined by
>
> $$P(k) = \int_0^N e^{-ks} M(s)\, ds \qquad (5)$$

Relation (3) shows that the age distribution of surviving equipment in the case of no growth can be obtained merely by taking the values in the life table and dividing by the average service life. We shall now express the age-distributions in a generalized

[8] Bradford F. Kimball: "General Theory of Plant Account Subject to Constant Mortality Law of Retirement", Econometrica, Vol. XI, No. 1, January 1943, pp. 61-82.

manner.

Let $x' = X/L$

and let $M_1(x') \cdot M(x)$

Then (3) becomes $M_1(x')/L$ (6)

We define $P(k) = LP_1(kL)$

and (4) becomes $e^{-kLx'} M_1(x')/LP_1(kL)$ (7)

where $$P_1(kL) = \int_0^2 e^{-kLs'} M_1(s')ds'$$

When the total stock of equipment is growing, one would expect a greater proportion of machines distributed at the younger ages. To illustrate how the age-distribution of surviving equipment changes under different rates of growth, generalized age-distribution curves have been plotted in Figure 2, based on the life table of Figure 1.

Values of $P_1(kL)$, based on Type $S_3$ data are shown in Figure 3. These values are important in the calculation of the data to follow.

Average Survivor Age Under No Growth

Our later work requires us to consider the relationship between the average service life L and the average survivor age S. The average survivor age is defined as the mean of the limiting age-distribution. Then for no growth,

$$S = 1/L \int_0^N xM(x)dx \qquad (8)$$

Let $$S_1 = \int_0^2 x' M_1(x')dx'$$

The ratio of average survivor age S to average service life L is $S_1$, the mean of the generalized no-growth age-distribution. $S_1$ can also be expressed as

$$S_1 = 1/L^2 \int_0^N xM(x)dx \qquad (9)$$

In the derivation of limiting depreciation ratios (ratios of depreciation reserve to gross equipment account) for the case of no growth, Kimball derives an expression containing our (9) above.[9]

$$\text{Limiting depreciation ratio} = 1 - 1/L^2 \int_0^N xM(x)dx \qquad (10)$$

Therefore,

$$S_1 = 1 - \text{limiting depreciation ratio} \qquad (11)$$

Later Kimball presents an expression for the limiting depreciation ratio under no growth.[10]

$$\text{Limiting depreciation ratio} = 1/2(1-\sigma^2) \qquad (12)$$

where $\sigma^2$ = variance of generalized mortality distribution $f_1(x')$. Substituting (12) into (11), we have a final expression for the ratio of average survivor age to average service life under no

[9] Ibid., relation (8.6), p. 74.

[10] Ibid., relation (10.10), p. 82.

growth:

$$S_1 = 1 - 1/2(1-\sigma^2) \qquad (13)$$

It follows that the ratio of average survivor age to average service life under no growth depends entirely upon the variance of the generalized mortality distribution.

Let us calculate $S_1$ under no growth and for the Type $S_3$ mortality data. The Iowa Type $S_3$ curve is almost identical with the h = 4.5 type curve under Kimball's classification. Kimball gives a .05 as the value for the generalized variance $\sigma^2$ of this curve.[11] Thus:

$$S_1 = 1 - 1/2(1-.05) = .53$$

Let $R_1 = 1/S_1$. Then $R_1 = 1.9$

For the Type $S_3$ mortality data, a group of similar machines kept at a constant total, subject to a constant mortality law, will have an average survivor age (as determined, say, from an equipment inventory) equal to .53 times the average service life. And given the average survivor age, one merely multiplies this age by 1.9 to obtain the average service life.

Average Survivor Age Under Uniform Rate of Growth

The average survivor age under a uniform rate of growth will depend on the value of kL. It was observed in Figure 2 that as kL increases there is a greater proportion of the total at the younger ages. The average survivor age will be .53L at kL = 0,

[11] Bradford F. Kimball: "A System of Life Tables for Physical Property Based on the Truncated Normal Distribution", Econometrica, Vol. XV, No. 4, October 1947, pp. 342-360.

decreasing for greater values of kL. The ratio of average survivor age to average service life under growth will be the mean of the generalized age-distribution under growth:

$$S_1 = 1/P_1(kL)\int_0^2 x' e^{-kLx'} M_1(x')dx' \qquad (14)$$

Unfortunately, the expression for $S_1$ is difficult to simplify and does not appear in Kimball's derivation of the growth depreciation ratios, as it did for no growth. Values of $S_1$ under growth may be calculated numerically by taking the first moments of the generalized age-distribution curves in Figure 2. These calculations were accomplished on the IBM 650 Electronic Computer, utilizing the Bell Interpretative Routine to facilitate programming. Since the values of $S_1$ appear in our application less often than those of the inverse form, $R_1$, the values of $R_1$ corresponding to various values of kL have been plotted in Figure 4. This chart provides the factors to convert average survivor ages to average service lives, under varying conditions of uniform growth as reflected in kL, for the Type $S_3$ mortality data.

Depreciation Ratios

An alternate method of obtaining ratios of average service life to average survivor age is by means of group straight-line depreciation ratios. Under conditions of no growth, we found the ratio of depreciation reserve to gross equipment account equal to .47. However, under conditions of growth we could expect the depreciation ratio to fall more or less in proportion to the younger average age of the surviving equipment. That is to say,

a younger plant implies less depreciation reserve in relation to the gross equipment account.

Kimball has derived a generalized expression for the limiting depreciation ratio under a uniform rate of growth k:[12]

$$1 - 1/kL\left(1/P_1(kL) - 1\right) \qquad (15)$$

From the values of $P_1(kL)$ in Figure 3, depreciation ratios have been calculated and plotted against kL as shown in Figure 5. A depreciation ratio computed on a basis of constant dollars to offset price-level changes, i.e., retirements and additions to gross account adjusted if necessary to an equivalent dollar basis, implies a certain kL value. And from a kL value one can determine $R_1$, the ratio of average service life to average survivor age, from Figure 4.

Determining Average Service Life From Average Survivor Age

Summarizing our results thus far, we have calculated $R_1$ as function of kL, where $R_1 = L/S$. In order to determine the average service life L from a given rate of growth k and a given average survivor age $S_1$, we may thus proceed by trying different values of L until we find the one for which the corresponding $R_1$ is equal to the corresponding L/S. By this procedure, Figure 6 has been prepared so an average service life can be read directly, given the uniform growth rate k and the average survivor age.

Determining Average Service Life from Median Survivor Age

The median survivor age is related to L and kL in a way

12 Bradford F. Kimball: "General Theory of Plant Account Subject to Constant Mortality Law of Retirement", op. cit., relation (10.9), p. 82.

similar to that of the average survivor age. It follows that the same kind of procedures and charts can be utilized if one prefers to work with the median in determining average service life. In Figure 7 we show the ratio of average service life to median survivor age for various values of kL derived from numerical analysis of the age-distribution curves in Figure 2. In Figure 8 we provide a means for reading the average service life directly, given the growth rate k and the median survivor age.

Determining Average Service Life from the Ratio of Average Survivor Age to Median Survivor Age

The medians of the generalized age-distributions in Figure 2 are characteristically less than the average, as can be seen by comparing Figures 4 and 7. As the value of kL increases, both the average and median survivor ages are lowered, but the median decreases by larger amounts. Each generalized age-distribution is thus characterized by a particular ratio of the average survivor age to the median survivor age, the ratio increasing with greater values of kL. In Figure 9 the relationship of this ratio to kL is shown. Thus if one calculated the ratio for a particular age-distribution, he could determine a kL value. With either the median or average together with the determined kL value, the average life could be determined.

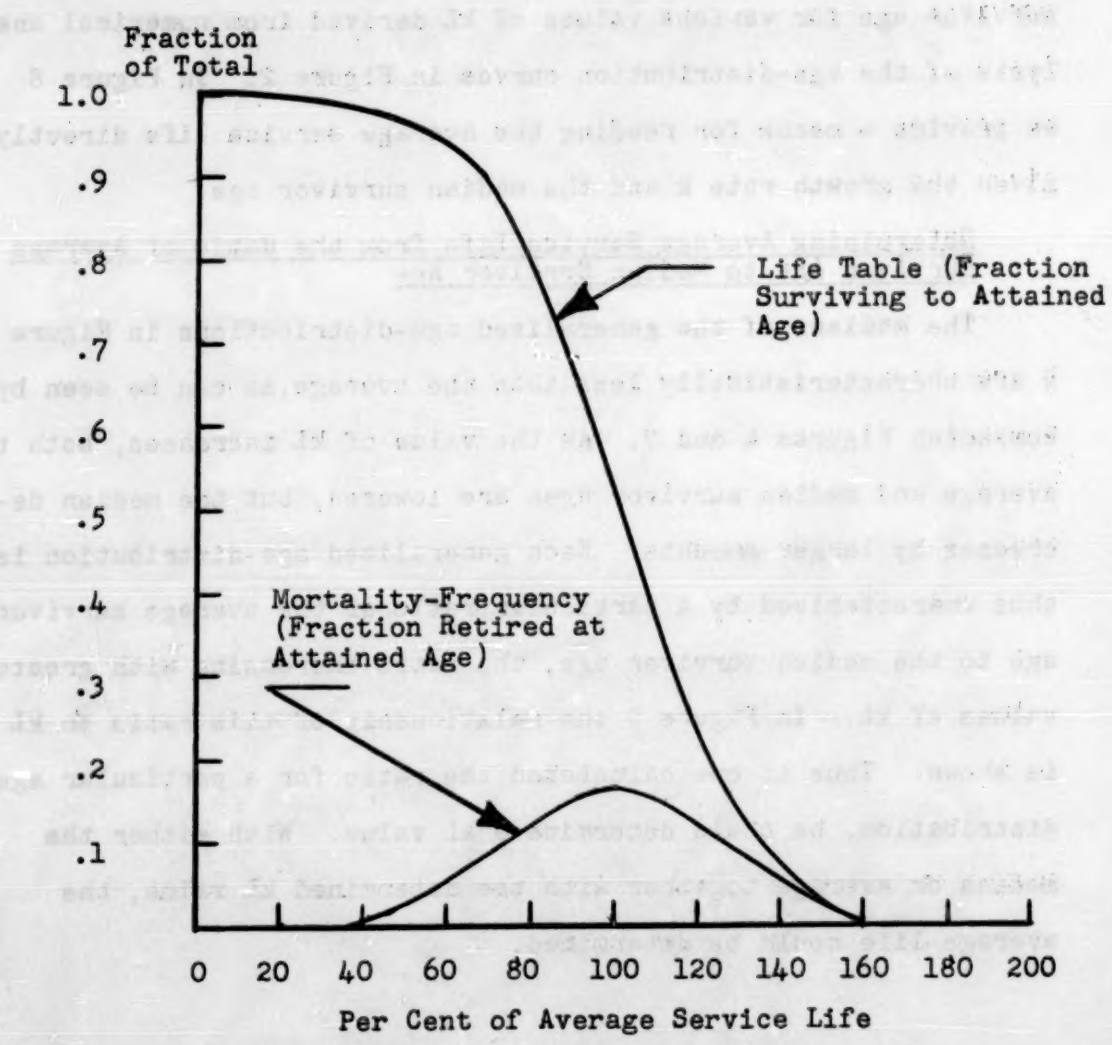


Figure 1. Iowa Type $S_3$ Mortality-Frequency and Life Table Data

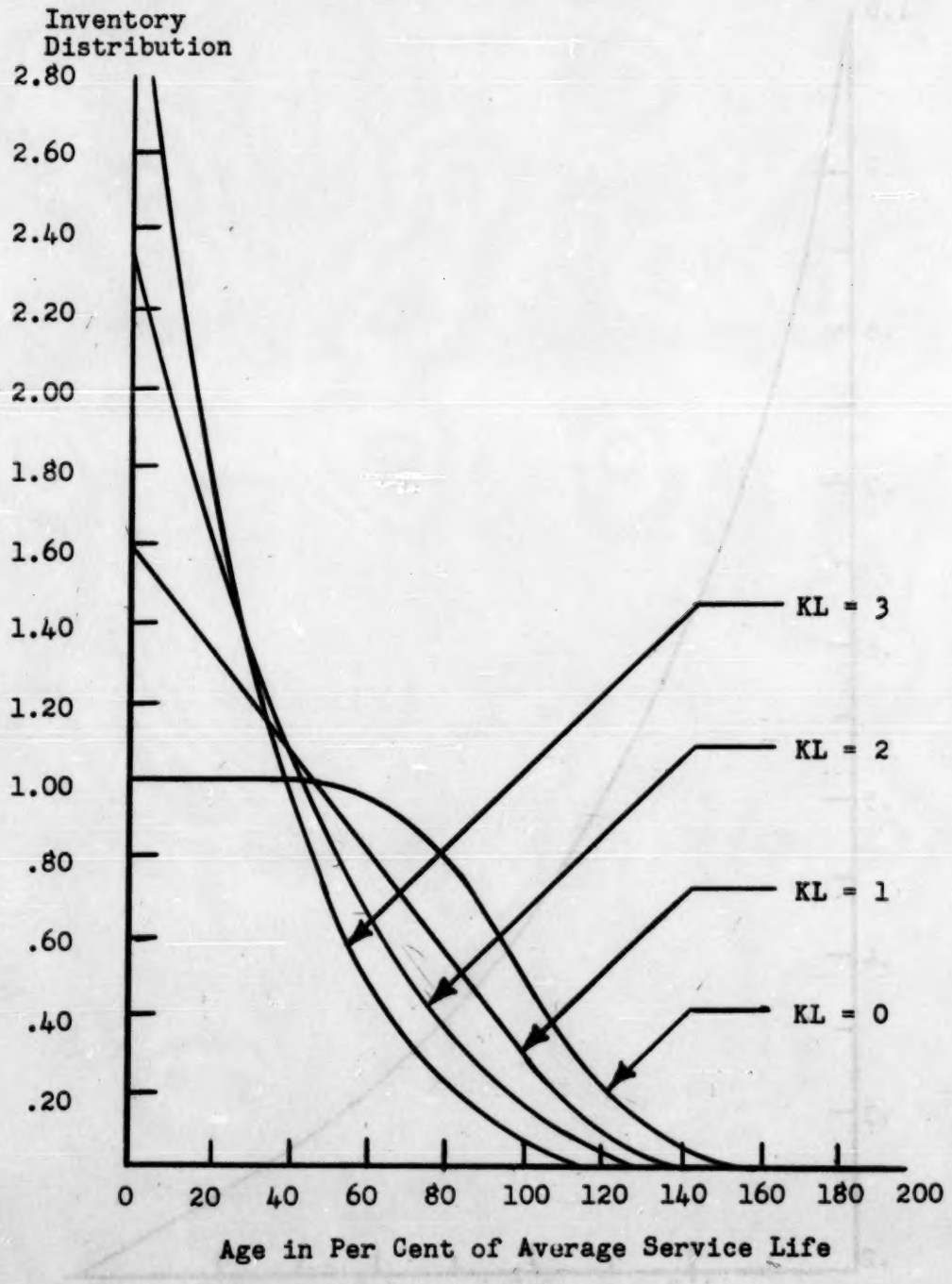


Figure 2. Generalized Age-Distribution of Surviving Plant

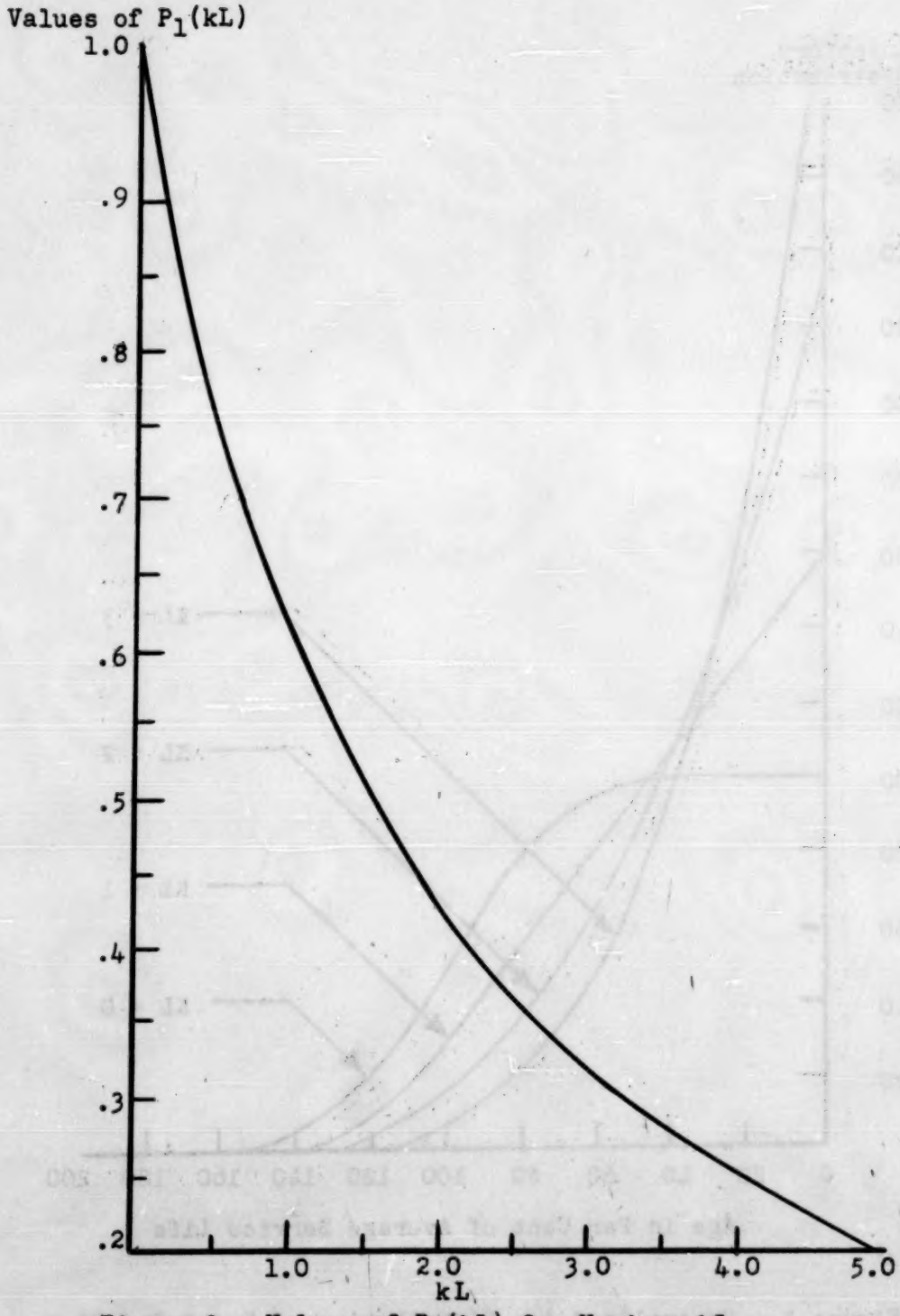


Figure 3. Values of $P_1(kL)$ for Various kL

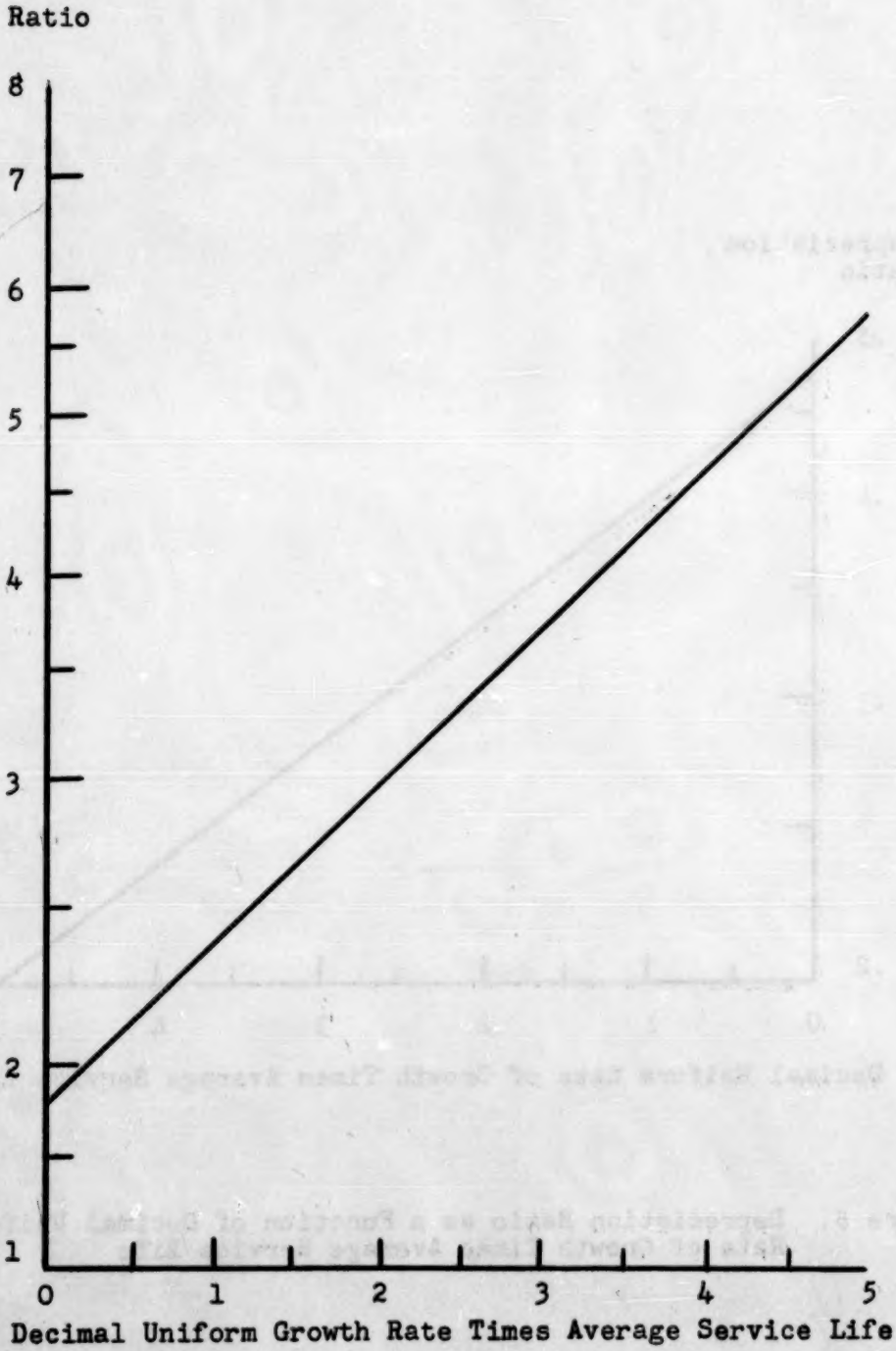


Figure 4. Ratio of Average Service Life to Average Survivor Age

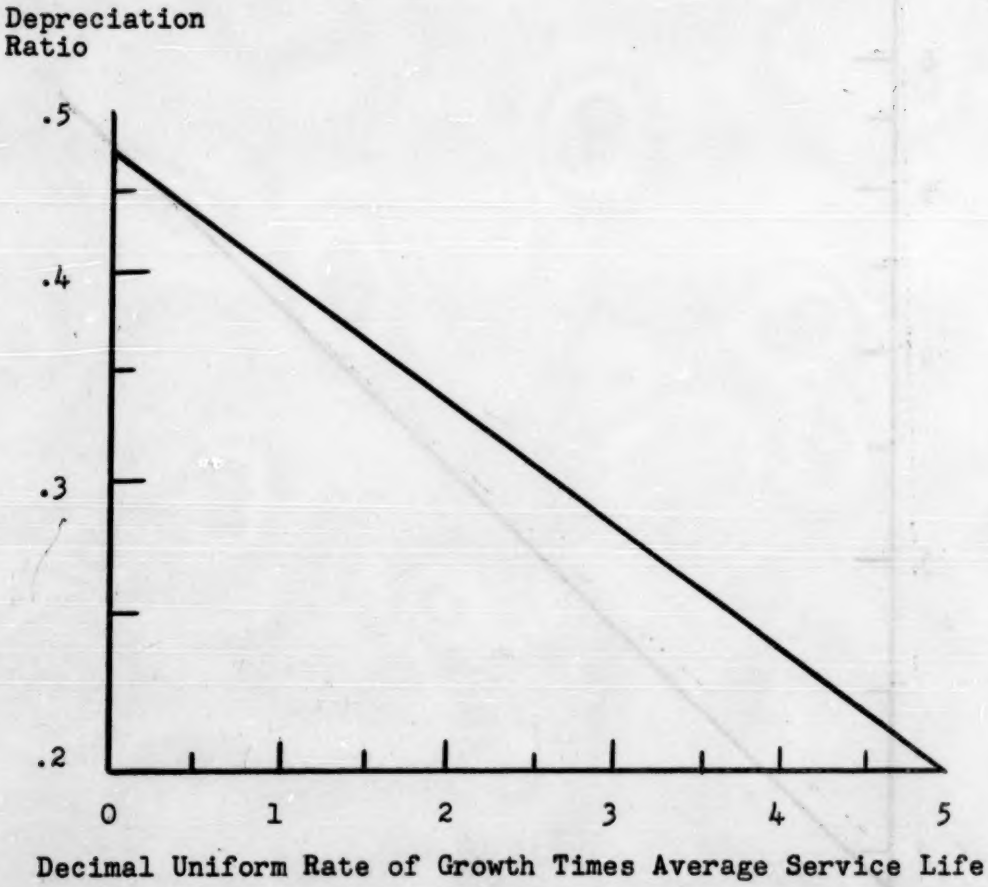


Figure 5. Depreciation Ratio as a Function of Decimal Uniform Rate of Growth Times Average Service Life

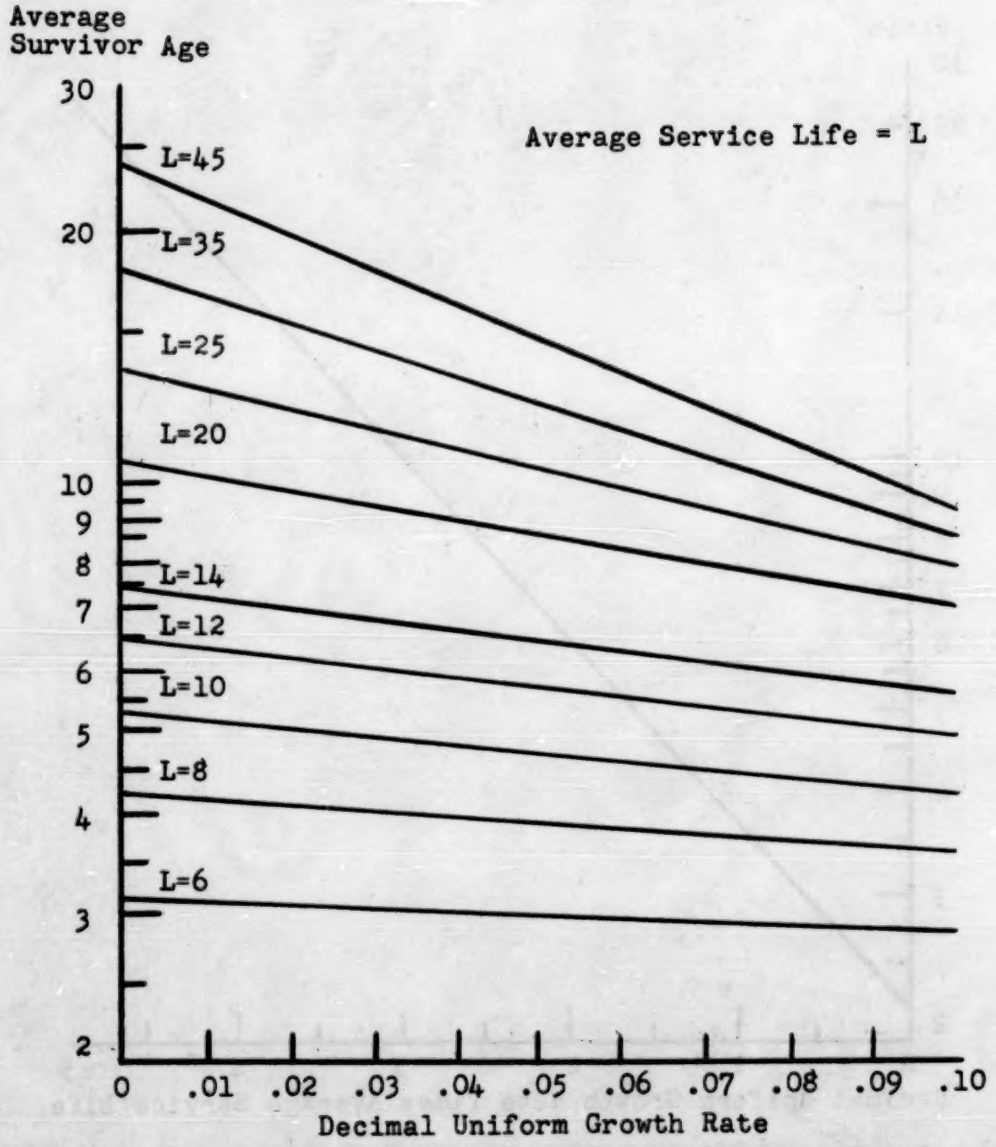


Figure 6. Average Service Life from Average Survivor Age and Decimal Uniform Growth Rate

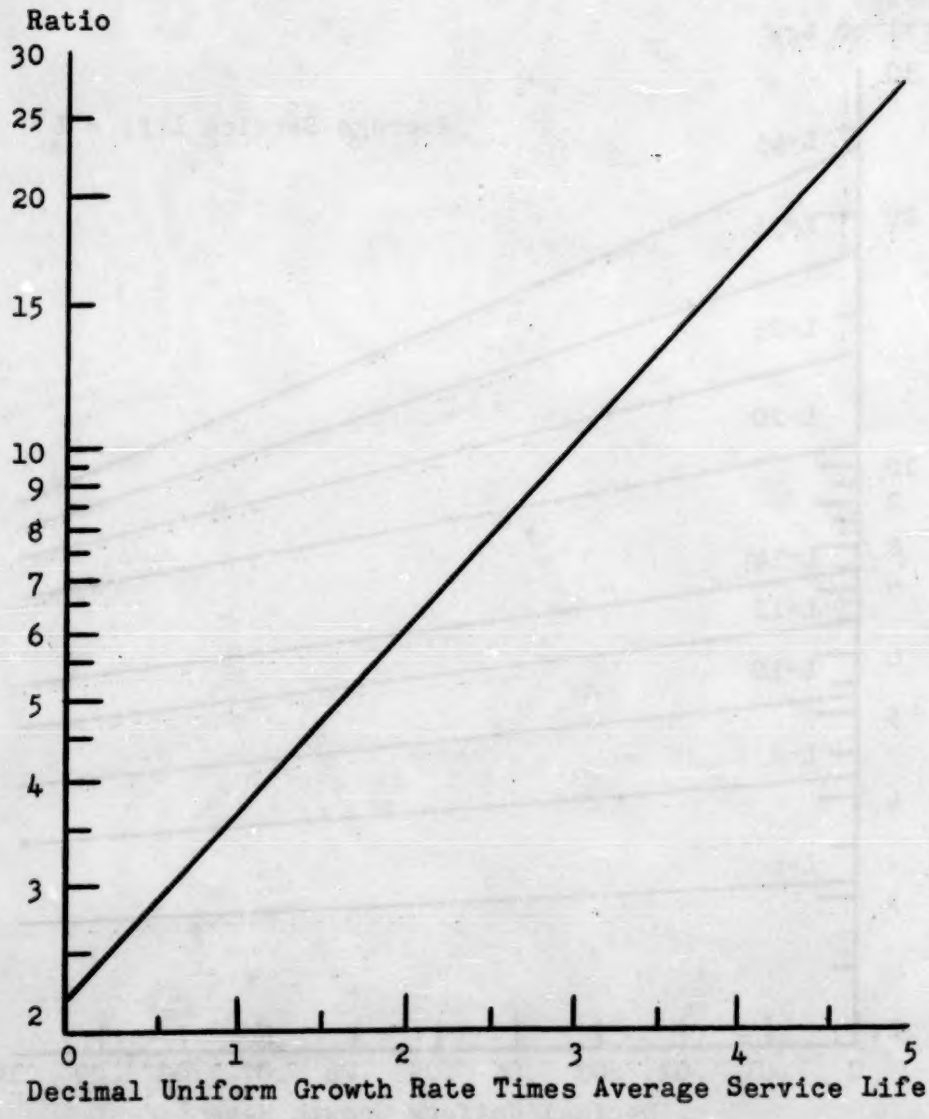


Figure 7. Ratio of Average Service Life to Median Survivor Age

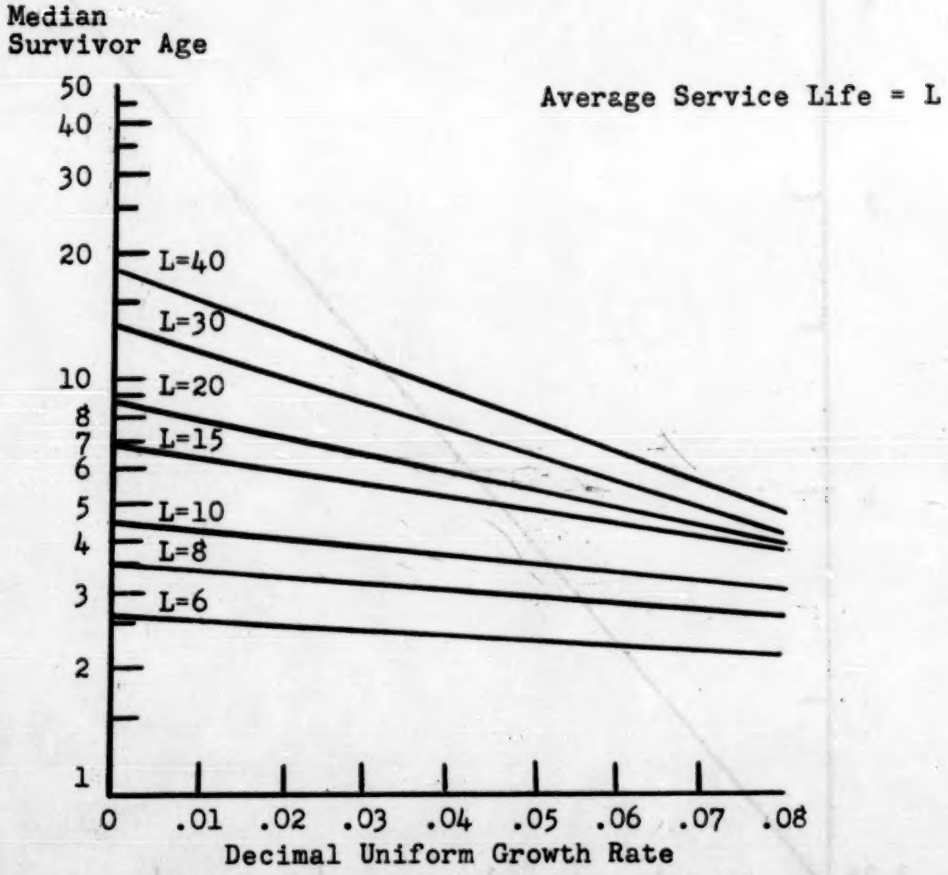


Figure 8. Average Service Life from Median Survivor Age and Decimal Uniform Growth Rate

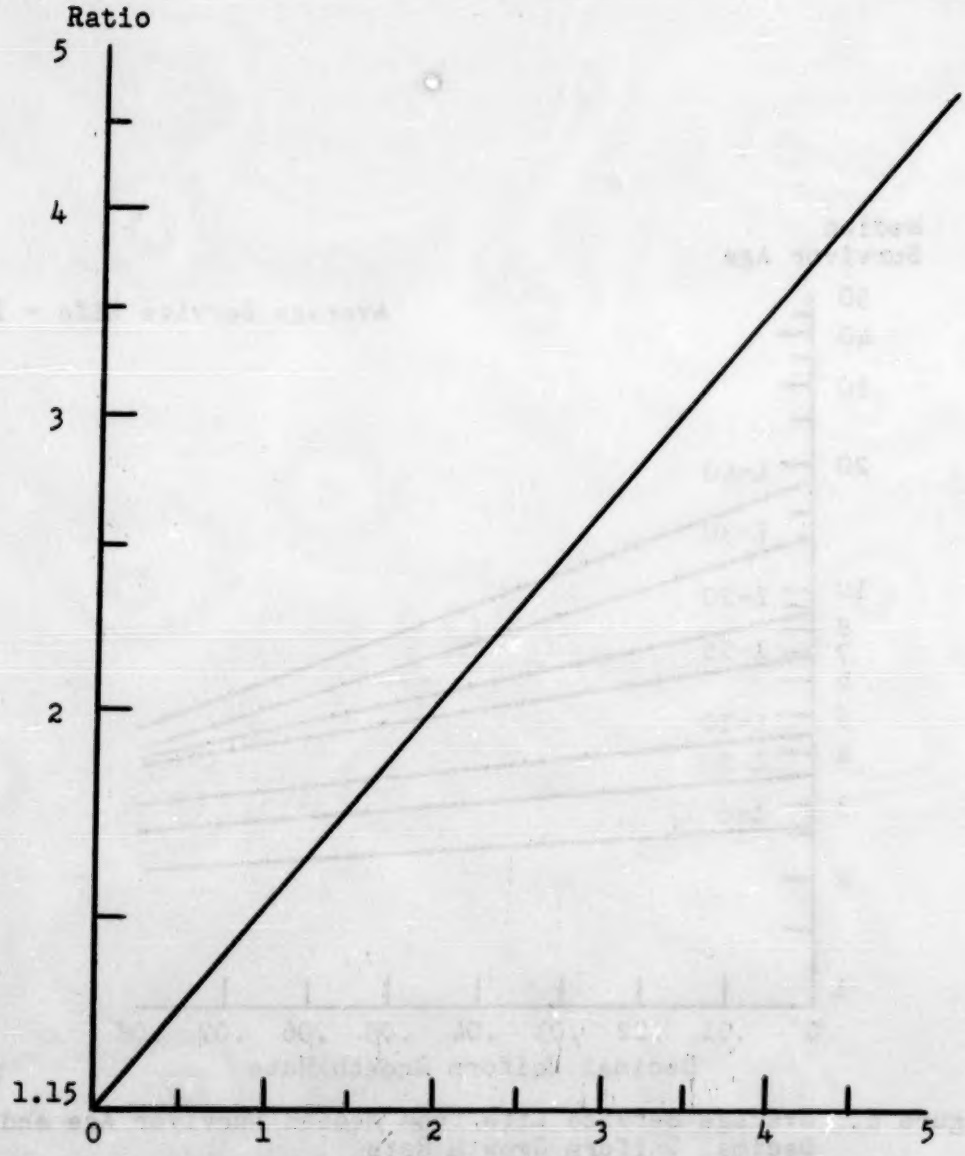


Figure 9. Ratio of Average Survivor Age to Median Survivor Age

# AN ECONOMIC STUDY of DATA PROCESSING SYSTEMS FOR ARCO OIL COMPANY

By

William C. Sand
Bell Telephone Laboratories

Electronic computers and data processing have become commonplace words in our business and government during the past few years and will become more significant in the future. The initial capital investment required to install data and computing equipment is relatively large, and application of these new methods should be properly appraised to optimize the investment. Failure to take into consideration all steps from receipt of raw data to the final solution may result, in many instances, in annual charges of a large investment and a system that is inefficient. In general, unless advantage is taken of the speed with which electrical computers and data processing equipment operate, it is difficult to optimize the system.

This report will illustrate the economic considerations for application of electronic processing equipment presently in use, or contemplated, for the Arco Oil Company, but it may also serve as a basic guide for many industries that are making cost studies to determine the economic feasibility of electronic computers and associated equipment. The report will illustrate the flow of data from the Arco distributing points to the refining plants and to the administrative headquarters. Ownership vs. rental costs will be presented for various methods of handling data. Although alternate means, on inspection, may not be feasible for this

company, they are presented since they might be considered in other enterprises. The discussion will be centered about the philosophy of their application.

The plans outlined in the study consist of a data communication network between ten branch offices and three base headquarters of the Arco Oil Company; each headquarters office has a computer.

## DATA SYSTEM STUDY REQUIREMENTS

System requirements which must be known are:

(1) Traffic points and amount of traffic.

(2) Routing of traffic.

(3) Character of traffic.

A knowledge is required of the number of times one station may want to contact the others, and what the holding time of these connections may be. For instance, branch offices will want to send information to, and receive information from, the Arco refinery, regarding shipments; to send information to the inventory and control points for additional items; and to send information to the accounting center for administrative purposes. In addition, it might be necessary for the various branch and central offices to communicate with each other.

This information will provide a knowledge of traffic in respect to length and quantity of communication channels and the co-channel occupancy feasibility. Both items affect the cost of interconnecting facilities.

The character of the traffic (voice, teletype, high-speed data, etc.) determines the type of communication channels required. Voice transmissions can be sent over a channel having a band width

of about 3000 cycles. Over this same type of channel, information can be sent at a rate of about 600 bits per second with present equipment. Recent investigations indicate that this bit rate might be quadrupled by using other methods.

Another type of channel can be designed which will allow a much higher bit rate to be transmitted. These are private line channels requiring more equipment and sometimes different cable facilities. The higher bit rate channels are more expensive to use than the common carrier connections, for the same amount of channel time.

The circuits we shall consider will be capable of handling data at rates of 70, 600, 750 and 1000 bits per second. A bit is a discrete item of information and each bit is discernible from the other. For example, in the teletype code a letter or character is composed of seven discrete electrical impulses. Six impulses are .0135 seconds long and the seventh is .019 seconds in duration. The time required to send one character is then 6 x .0135" plus .019", the sum being .1000 seconds. Therefore, in one second, 70 bits or impulses are transmitted. The 600, 750 and 1000 bit transmissions, of higher speed, are similar in principle.

## DESCRIPTION OF BRANCH OFFICE PLANS

### Plan I

Sketch I depicts the equipment arrangements for branch offices employing machines on which operators can type characters onto coded cards. These cards can then be processed through a card-to-tape convertor and the tape fed into data transmitting equipment.

These cards can be punched at the convenience of the operator.

When a sizable number have been prepared, the branch office will place a long distance telephone call to the main inventory point or refinery, or other base headquarters. A data subset can be connected to the line and switched to the receive position manually, or it can be unattended and switched on automatically when a call comes in. The operator of the originating data processing unit at the branch office will receive a signal and then feed the cards into the card-to-tape convertor, which in turn will be processed through the data transmitter which sends out pulses through the toll network normally used for voice. Receipt by the headquarters is on a similar data receiver, and the data are recorded on a tape which can either be processed immediately by a computer or stored and processed at a later date.

It should be mentioned here that the computer can operate at a much faster rate than that at which the data are transmitted; by the proper time-sharing of equipment, as many as 10 simultaneous transmissions, each from a different office, can be handled by the computer. This would require 10 data receiving sets, one for each transmitting office, and a synchronized switching system.

Plan II

Sketch II illustrates the equipment arrangement whereby a teletypewriter (TTY) with a paper tape is prepared. The tape is fed into a transmitter distributor. Electrical signals are delivered to the recorded carrier subset, where a magnetic tape is prepared. This tape can be processed through the data transmission set when feasible. The recorded carrier subset stores information at the TTY bit rate of about 70 bits per second and transmits at

about 600 bits per second.

Use of this method substitutes the preparation of a punched card with the use of a perforated paper tape which can also serve as a permanent record. Of course the magnetic tape used in the recorded carrier can be stored, but it is quite inconvenient with present equipment designs.

As described in Plan I, a telephone connection is made in preparation for the transmission of data.

Plan III

Sketch III depicts the use of a relatively slow operating system (TWX) at 70 bits per second. In this arrangement the teletype operator contacts a central switching system, which completes the connection to the called teletype station much the same as a telephone call. After the branch office has contacted the headquarters, information can be passed back and forth between the two teletype machines. Should the necessity arise for teletypes of one system to be connected in a conference hookup with those of another system, central switching arrangements are available.

Plan IV

Sketch IV illustrates a "Dataphone" system, with the same bit rate as III above. The teletype operator places a telephone call over standard voice circuits, and when the called party answers, she is informed that a dataphone message is to be sent. Originating and terminating subsets are switched to the type position and the two teletype machines can send and receive to each other.

This plan differs from III, above, in that ordinary voice

channels are employed for transmission of TTY signals rather than special lines and switching networks. Conference call arrangements permitting intersystem connections can be made as in Plan III. In addition, a telephone conversation can be carried on before or after the data are sent.

## OPERATING CHARACTERISTICS OF BRANCH OFFICE PLANS

The key-punched cards in Plan I are universally used in data and computer equipment. It might be necessary in future operations for the branch offices to perform certain computations with a local computer which will operate from an input of punched cards. Key punch cards also provide a permanent record, but this is an expensive and relatively inefficient method of retaining information, since magnetic tape can store the same amount of information in a smaller volume and can be reused. The output magnetic tape of the card-to-tape convertor can also be stored, if needed for future reference or processing.

Teletype methods as used in Plan II have been an excellent means of communication for years. When adapted to this plan, however, a certain amount of redundancy is introduced. Data storage is provided on the TTY perforated tape as well as on the magnetic tape in the subset. Because data-subset-to-TTY-machine has an 8 to 1 ratio of handling data, it is necessary to provide buffer storage in the subset. If the tape is to be stored and reused, consideration must be given to the teletype code stored on the tape and whether it can be processed by other machinery.

Many other types of data machines are available which could use the recorded carrier subset. The code that other equipment

types use might be more adaptable than TTY to future computers and data equipment and hence eliminate a possible translation.

Plan III uses a standard teletype service and where the bit rate is low and teletype records satisfactory, this may be the most economical operation. The machine is simple to operate for anyone familiar with a keyboard. Maintenance is no problem, since the nominal monthly rental covers these costs. Although many private lines do exist, message rate billing similar to telephone service is the general practice. Teletype message rates, incidentally, are approximately 25% less than talking channel rates for the first three minutes.

A major disadvantage in the use of Plan III is the lack of a relatively inexpensive storage medium for future requirements.

Of the many plans a company might choose, each must be studied thoroughly for the application involved. It might be well to point out that if a buffer storage is provided for accumulated data, like the tape in the recorded carrier subset, the company could record during the daytime and send data during the evening, taking advantage of lower rates. Both the telephone company and dataphone user benefit, for it is most desirable to spread the use of telephone channels over longer periods of time. By keeping the traffic load as small as possible during a given interval of time (busy hour call seconds), less telephone equipment is needed. Some considerations the dataphone user has to take into account for evening operation are possible wage differentials for "off normal working hours", extra lighting load, and inconvenience of possible equipment failures during evening hours.

Plan IV, while similar to Plan III, utilizes the flexibility of telephone local and toll switching systems, employs relatively simple and trouble-free equipment, does not require a large initial capital investment, and eliminates the need for maintenance personnel or separate maintenance contracts. In addition, a talking path is established which might improve the service.

Two disadvantages are relatively expensive (space-wise) permanent storage, and slow speed of operation. Where requirements are such that the cost of additional channel time to transmit data is less than the annual charges of higher-speed equipment, the slow-speed dataphone may suffice. However, future requirements must not be overlooked, for at a later date punched cards or magnetic tapes might be required to feed information into a computer, and a teletype might not be satisfactory. This system may be ideal for a new office or business where the information rate is initially low. A year or two later when the volume of traffic has increased, higher-speed data systems can be installed. A present worth study of these deferred investments should aid in making a proper decision.

For cost comparisons in this study it was assumed that a reperforator and teletype transmitter distributor would be used, since this will enable a TTY operator to prepare a tape before transmitting on telephone channels. Less channel time will be required, for information on the tape is transmitted at a uniform rate.

## COST COMPARISONS OF BRANCH OFFICE PLANS

The following table summarizes and compares the costs of the branch office plans:

## Annual Charges

(These charges are for three units. The equipment charges include some items which may be common to many key punch or teletype machines, and quantities are not increased linearly with key punch or teletype machine requirements.)

| | Rental | Ownership |
|---|---|---|
| **Plan I** | | |
| Equipment | $2,268.00 | $4,356.00 |
| Communication time (voice channels) | 480.00 | 480.00 |
| Total | $2,748.00 | $4,836.00 |
| **Plan II** | | |
| Equipment | $1,620.00 | $1,383.00 |
| Communication time (voice channels) | 480.00 | 480.00 |
| Total | $2,100.00 | $1,863.00 |
| **Plan III** | | |
| Teletype equipment | $ 1,440.00 | Cannot be purchased |
| Communication time (TTY channels) | 13,150.00 | |
| Total | $14,590.00 | |
| **Plan IV** | | |
| Teletype equipment | $ 2,160.00 | Cannot be purchased |
| Communication time (voice channels) | 15,780.00 | |
| Total | $17,940.00 | |

In using Plan I it would be more economical to rent the equipment than own it. Maintenance, depreciation, and cost of money are higher for the owner than for the lessor. This is not always true, but in this case the lessor can spread his maintenance and depreciation costs over a longer life and more equipment.

Plan II illustrates costs favoring ownership of equipment. However, the factors to be considered here are whether the method of operation is flexible enough, whether information can be

easily stored, and whether the methods reach early obsolescence.

Plan III does not appear acceptable for this system unless unusual circumstances exist.

Plan IV has characteristics similar to those of III and must be rejected. (It should be noted that communication channel time is very high and costly.)

The comparisons for Plans I and II assumed equal transmission speeds. However, suppose that the machine of Plan II could only transmit at 600 bits a second and Plan I at 1000 bits a second; and assume one less machine is needed for Plan I. The rental cost comparison for these plans would appear as follows:

| Plan I | Plan II |
|---|---|
| $1,988.00 | $2,100.00 |

Plan I is more favorable than Plan II, for not only is one less machine required, but the cost for communication channel time has been decreased by $184.00. The advantage of higher speeds is being illustrated.

If a 600 bit rate is used, Plan II is cheaper than Plan I. If Plan I operates at a 1000 bits per second rate, and Plan II at 600, then Plan I is cheaper. In practice, however, Plan II can also function at the 1000 bit rate. The example is given to illustrate the importance of channel time in computing the annual costs.

The equipment chosen illustrates two different methods of transmitting data, and two different charges, but before a decision could be made choosing the cheaper method, it was necessary to decide whether or not the punched cards or the tape of Plan

I have another function which might offset their higher costs. If the punched cards cannot be feasibly utilized, then the teletype paper tape output can be stored on a magnetic tape, if desired.

For teletype service in Plans III and IV, if only 10 minutes per day transmission time is required, the total annual charges would be $972.00. However, at a bit rate of 70 per second, only 15 orders per day could be processed in 10 minutes.

In this study, no comparison was made of what future equipment might be used and what the present worth of annual charges might be. It is entirely possible that such a program should be put into effect. With the rapid advancements being made in the communication processing field, early obsolescence is indicated, and therefore future methods should be thoroughly investigated.

COMPUTER OPERATIONS

Computer to computer transmissions, not mentioned in the above branch offices study, would demand an annual rental cost of $319,911 and annual ownership costs of $274,100. (Both figures include a $52,800 cost for communication channel time.) Computer ownership indicates the most economical operation, but two of the biggest factors in the computer market today are the acquisition of qualified operating personnel and the questionable reliability of the systems. (While these factors could be reflected in the cost study, they generally are not because of the optimistic outlook of the engineer making the study.) Furthermore, before a company makes a decision on the purchase of a computer, it should analyze the computer's utility. For instance, a typical

computer can process information at a rate of 100,000 bits per second. For an eight hour day this amounts to a capacity, at 80% work time, of $.8 \times 8 \times 10^5 \times 60 \times 60 = 2.3$ billion bits. A very large operation can utilize this enormous capacity, but many plants cannot. A more feasible arrangement will be discussed in the summary.

Communication channel time for computer to computer hookups is costly. The prevailing feeling is that, if two computers could be connected together, much terminal processing work with key punch units or similar devices might be eliminated; but channels for computers must be especially designed and they require much more Central Office equipment, thereby necessitating higher rentals.

## SUMMARY AND RECOMMENDATIONS

When considering the utilization of data processing or computer equipment, the following operations should be considered:

(1) Investigation of several types or methods of operation.

(2) Study of machine time required.

(3) Study of the ratio of idle to busy machine time.

(4) Study of the method of storing data, if storage is necessary.

(5) Planning for multi-use of processed data.

(6) Determination of transmission time and cost of channel time, if transmission of data to a distant point is necessary.

(7) Comparison of ownership versus rental costs.

(8) Comparison of machine versus manual methods.

(9) Computation of annual charges.

(10) Investigation and preparation of a present worth study of future equipment requirements.

For the ten branch offices and three headquarters of Arco Oil Company, the final presentation of total annual charges would appear as follows (Plans III and IV having been discarded):

| | Plan I | | Plan II | |
|---|---|---|---|---|
| | Rent | Own | Rent | Own |
| Per Branch Office | | | | |
| 20 data machines plus 634 hours channel time | $ 21,490 | $29,430 | $ 14,490 | $22,290 |
| Per Headquarters | | | | |
| Computer and equipment (includes channel time) | $319,911 | | $274,100 | |

It should be noted that the computer time in each headquarters is running at 25% of capacity. The study presented included only orders originated by the branch offices. (Other administrative functions are carried on at headquarters which are entirely independent of the information generated by the field. Discussions with the Arco people disclosed that one computer was operating about 12 hours per day.)

The Arco Company can justify the use of computers and high-speed machinery because it has the traffic requirements, but many users or potential users of equipment do not. To overcome inefficient methods, in such situations, a centralized computing service is proposed. This computing center could receive raw data from its customers in the form of mark sensed cards, punched cards, paper or magnetic tapes, or typed information by United States mail. A faster, more efficient, and probably more economical method is to transmit the information over communication

channels, as outlined in the cost study. The computer center could solve the problem and transmit the answer to other locations or to the originating office. A fee could be charged by the center for performing the computing functions. This method of operation would be economically feasible, for the annual charges on computer investment would not be incurred by each company and greater flexibility of operation would result.

The glamour of being able to do a "10 day" job in "10 minutes" can lead to millions of dollars of inefficiently invested money. Only by considering all factors, no matter how seemingly insignificant, can an accurate answer be given for each case studied.

Editor's Note

Although the name of the oil company has been changed, the foregoing article is based upon an actual cost study. The data processing systems recommended are now in operation.

Another article on the subject of data processing equipment will appear in a forthcoming issue of The Engineering Economist - "Economic Analysis of Data Processing Equipment", by R. B. Orensteen and M. D. Pines.

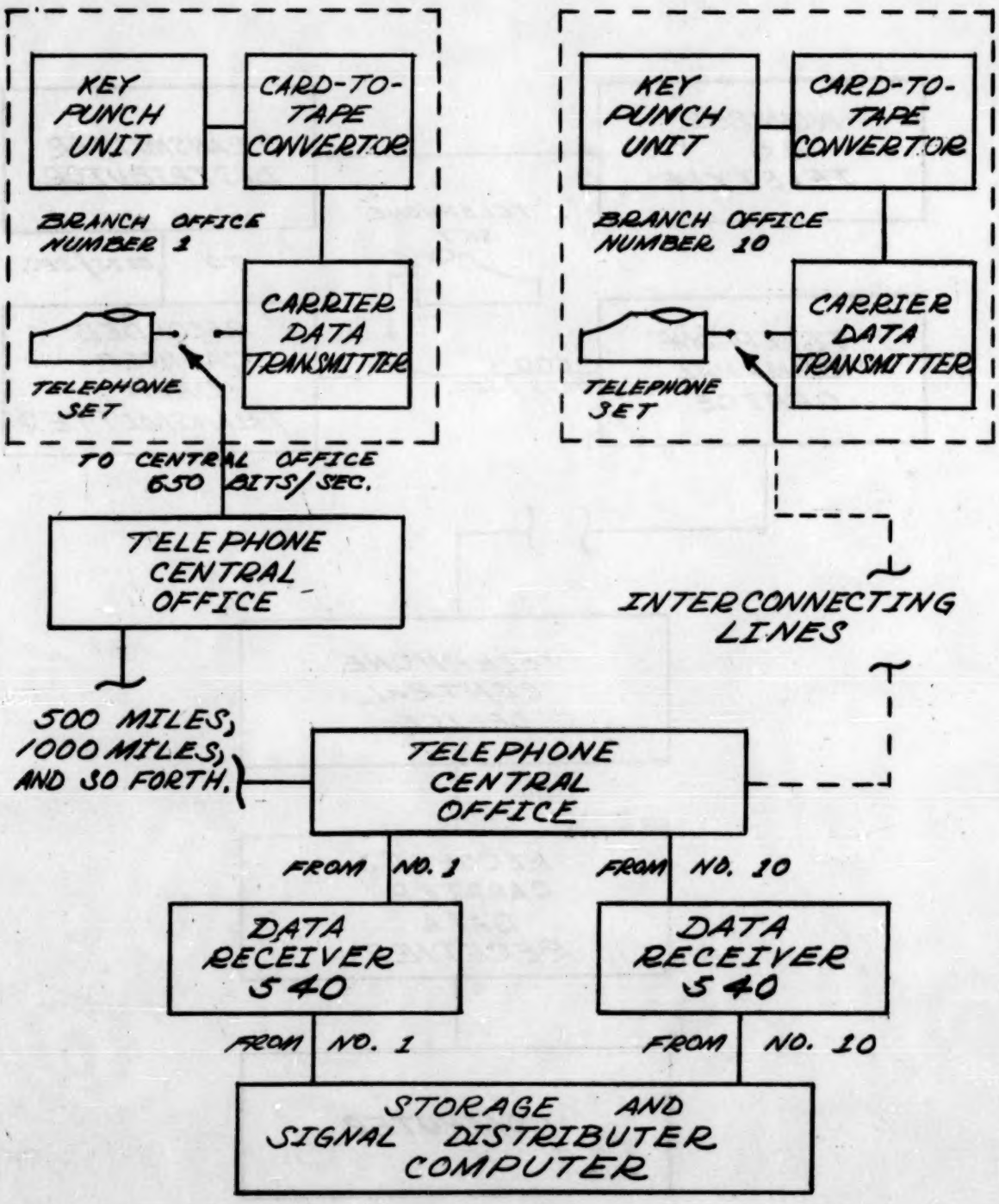
KEY PUNCH UNIT
CARD-TO-TAPE CONVERTOR
BRANCH OFFICE NUMBER 1
CARRIER DATA TRANSMITTER
TELEPHONE SET
KEY PUNCH UNIT
CARD-TO-TAPE CONVERTOR
BRANCH OFFICE NUMBER 10
CARRIER DATA TRANSMITTER
TELEPHONE SET
TO CENTRAL OFFICE 650 BITS/SEC.
TELEPHONE CENTRAL OFFICE
INTERCONNECTING LINES
500 MILES, 1000 MILES, AND SO FORTH.
TELEPHONE CENTRAL OFFICE
FROM NO. 1
FROM NO. 10
DATA RECEIVER 540
DATA RECEIVER 540
FROM NO. 1
FROM NO. 10
STORAGE AND SIGNAL DISTRIBUTER COMPUTER

FIGURE 1.

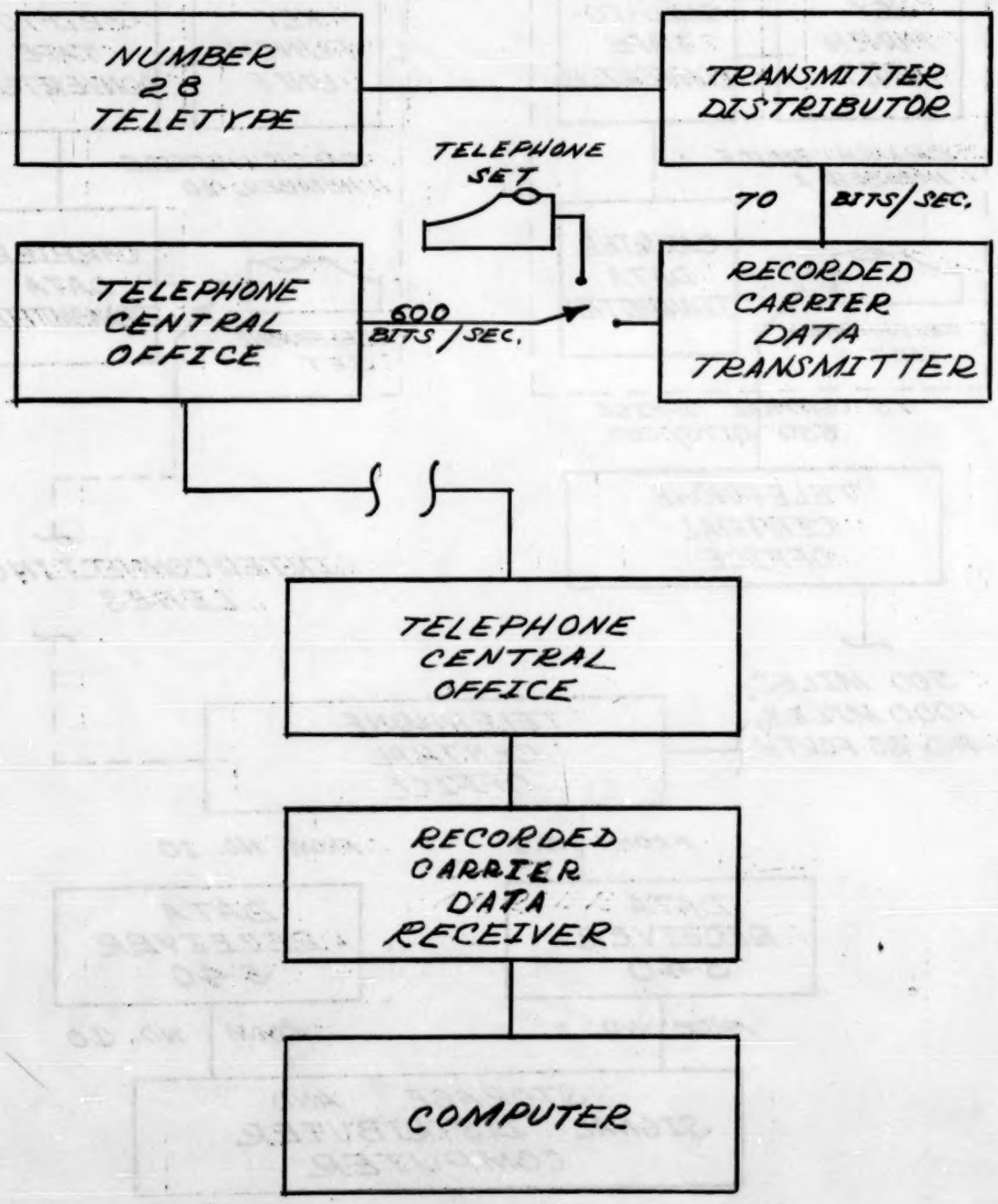
NUMBER 28 TELETYPE
TRANSMITTER DISTRIBUTOR
TELEPHONE SET
70 BITS/SEC.
TELEPHONE CENTRAL OFFICE
600 BITS/SEC.
RECORDED CARRIER DATA TRANSMITTER
TELEPHONE CENTRAL OFFICE
RECORDED CARRIER DATA RECEIVER
COMPUTER

FIGURE 2.

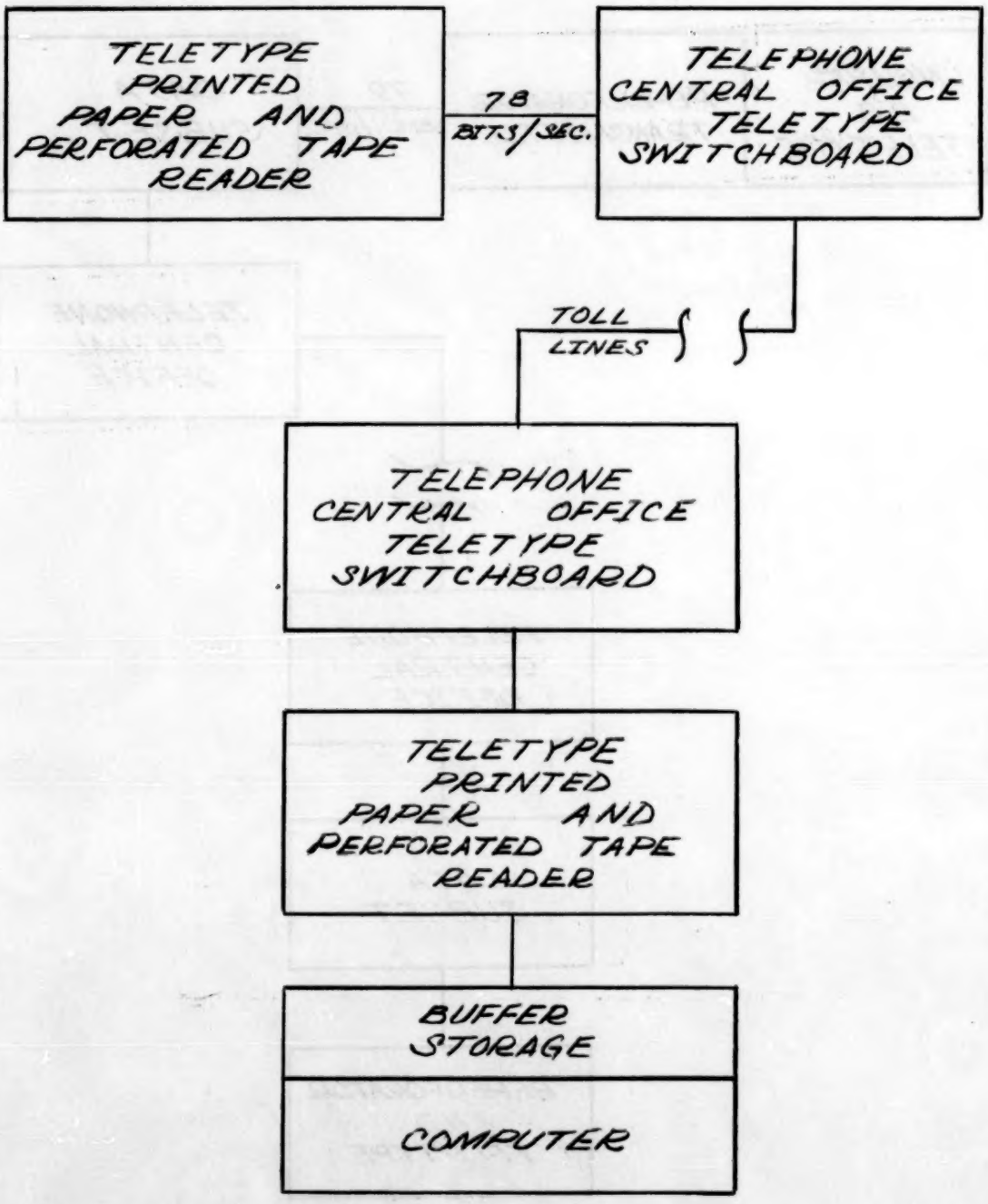
TELETYPE PRINTED PAPER AND PERFORATED TAPE READER
75 BITS/SEC.
TELEPHONE CENTRAL OFFICE TELETYPE SWITCHBOARD
TOLL LINES
TELEPHONE CENTRAL OFFICE TELETYPE SWITCHBOARD
TELETYPE PRINTED PAPER AND PERFORATED TAPE READER
BUFFER STORAGE
COMPUTER

FIGURE 3.

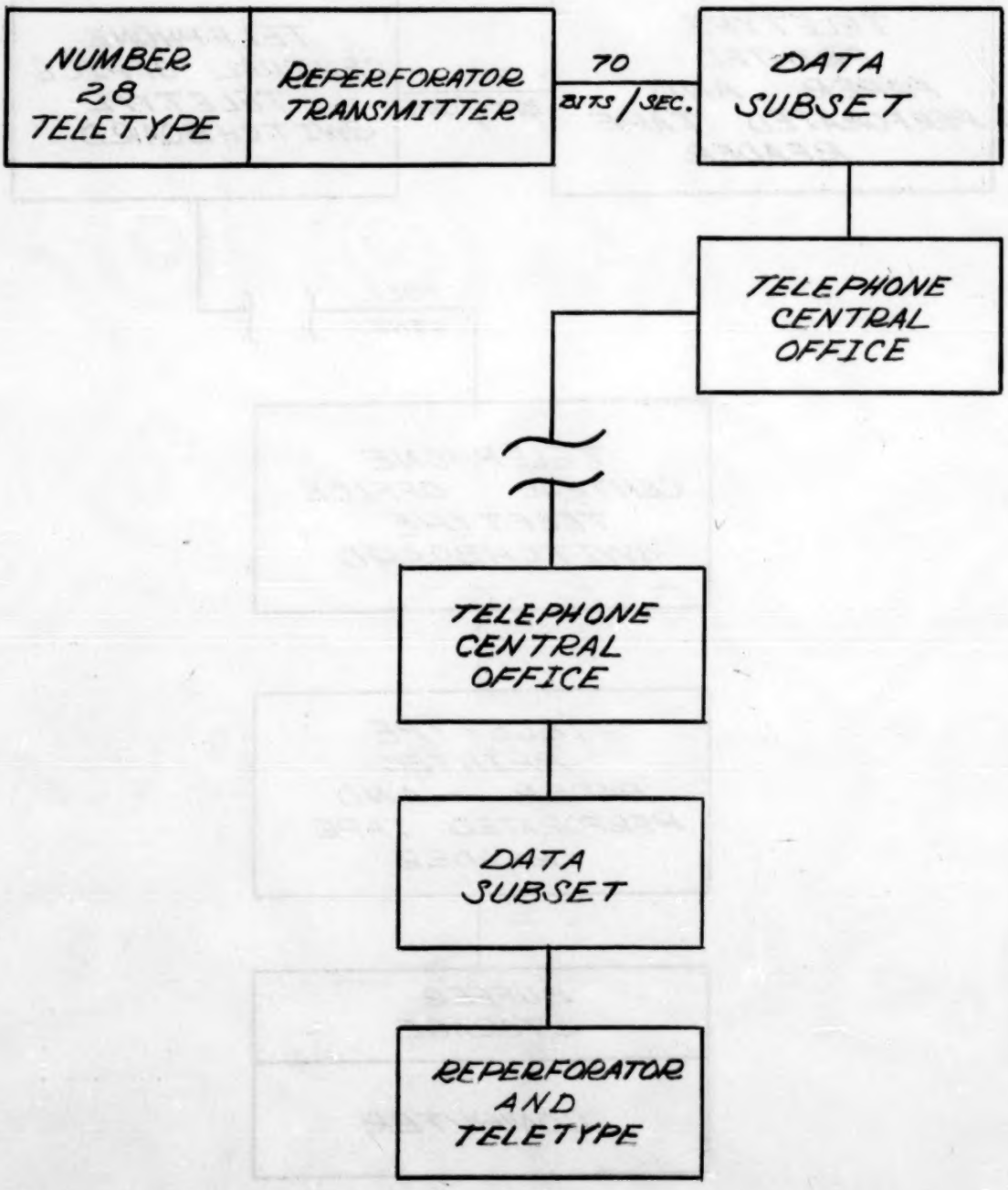
NUMBER 28 TELETYPE
REPERFORATOR TRANSMITTER
70 BITS / SEC.
DATA SUBSET
TELEPHONE CENTRAL OFFICE
TELEPHONE CENTRAL OFFICE
DATA SUBSET
REPERFORATOR AND TELETYPE

FIGURE 4.

# APPLYING THE TECHNIQUES OF ENGINEERING ECONOMY to the SELECTION OF LIFE INSURANCE POLICIES

By

Gerald W. Smith
Iowa State College

## INTRODUCTION

A pamphlet recently distributed by the Veterans Administration announced:[1]

> A law effective January 1, 1959 permits term insurance issued under section 621 of the National Life Insurance Act of 1940, which is in force, to be:
>
> (1) Exchanged for a limited convertible 5-year level premium term policy, OR
>
> (2) Converted to one of six permanent plans of insurance.

Ordinarily the selection of one of the eight alternatives, i.e., cancellation, limited convertible, or the six permanent plans, is made in an arbitrary manner by simply selecting the alternative which is the best "hunch" of the policyholder.

To demonstrate that even the apparently complex alternatives of life insurance policies can be evaluated by application of the techniques of Engineering Economy, the author has prepared this paper. The objective is the illustration of the type of analysis available, not the solution of a specific problem.

National Life Insurance has been used in the illustration

[1] Veterans Administration: Information and Premium Rates for Veterans Special Life Insurance (Non-Participating). Pamphlet 90-2. Veterans Administration, Washington 25, D. C., November 1958. P. 2.

only because the rates are readily available and the selection of alternatives is a current one for all policyholders.

ASSUMPTIONS

Inspection of the rate tables[2] indicates that the highest annual cost premium for a policyholder under 40 years of age is that of the 20 year endowment policy. Assume that an amount of cash equal to this cost is available to the policyholder each year for 20 years, and that this cash will be used to purchase $1000 worth of life insurance, with the remainder, if any, to be invested.

Since the analysis includes the assumption of investment, it is necessary to assume a rate of return, after income taxes, available to the policyholder. In the example which follows a 4% rate of return has been used. Such rates are currently available on many high-grade common and preferred stocks, and on a few medium grade corporate bond issues.

To establish the specific annual cost of the various alternatives, it is necessary to assume the age of the policyholder; in this case, an age of 25 has been arbitrarily selected.

THE ALTERNATIVES

The eight alternatives are briefly described below. Alternative numbers correspond with those of the rate pamphlet and Figure 1. For the age assumed, 25, the rate for the 20 year endowment policy is $38.92 per year.

[2] Ibid., p. 6-12.

0 - Insurance is cancelled and the 20 payments of $38.92 are invested.

1 - The beginning rate of the term insurance is $0.95 per year. The premium is increased each 5 years with rates of $0.95, $1.19, $1.66, $2.85, and $4.86 respectively. The policy cannot be continued beyond the insured's 50th birthday. The difference between $38.92 and the premium is invested for the first 20 years. During the following 5 years, age 45 to 50, premiums are paid from the accumulated investment. Thereafter, the policy is cancelled and the accumulation continues.

2 - Ordinary life premiums of $11.51 are paid throughout the life of the policyholder. During the first 20 years, $38.92 - $11.51 = $27.41 is invested each year. Thereafter, the premiums are paid from the accumulation.

3 - 20 payment life premiums of $20.17 are paid for the first 20 years. The remainder, $38.92 - $20.17 = $18.75, is invested each year. Thereafter, the accumulation continues.

4 - 30 payment life premiums of $15.19 are paid for the first 30 years. During each of the first 20 years, the balance of $38.92 - $15.92 = $23.73 is invested. During the next 10 years, premiums are paid from the accumulation. Thereafter, the accumulation continues.

5 - 20 year endowment premiums of $38.92 are paid for the first 20 years. At the 20th year the $1000 amount is withdrawn

and invested, with accumulation continuing.

6 - Endowment at age 60 premiums of $19.10 are paid for the first 35 years. During each of the first 20 years, the balance of $38.92 - $19.10 = $19.82 is invested. From this accumulation premiums are paid over the next 15 years. The $1000 endowment is then withdrawn and is invested thereafter.

7 - Endowment at age 65 premiums of $16.26 are paid for the first 40 years. During each of the first 20 years the balance of $38.92 - $16.26 = $22.66 is invested. From this accumulation premiums are paid over the next 20 years. The $1000 endowment is then withdrawn and invested thereafter.

CONCLUSIONS

Observation of Table 1 and Figure 1 indicates that the best alternative for "age at death" brackets can be shown as follows:

| Age at Death | Best Alternative |
|---|---|
| 25 to 50 | 1 |
| 50 to 64 | 2 |
| 64 or more | 0 |

Since this is only a categorical answer, and "age at death" can at best only be guessed by a policyholder, one must go one step farther, noting that alternative 1 will generally be the best gamble. It is superior to alternative 2 for all but an "age at death" bracket of 50 to 66 years. Compared with alternative 0 it is vastly superior early in life and only slightly inferior thereafter.

"Cash surrender" and "loan" benefits are never so great as

Table 1. Accumulated Cash and Life Insurance Values in dollars versus Age in years for the 8 available alternatives.

| Premium duration, yrs. | | inf. | 20 | 30 | 20 | 35 | 40 |
|---|---|---|---|---|---|---|---|
| Age | Plan # 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 25 | 39 | 1038 | 1027 | 1019 | 1024 | 1000 | 1020 | 1023 |
| 30 | 211 | 1206 | 1148 | 1102 | 1129 | 1000 | 1107 | 1123 |
| 35 | 467 | 1455 | 1329 | 1225 | 1285 | 1000 | 1238 | 1272 |
| 40 | 779 | 1755 | 1549 | 1375 | 1475 | 1000 | 1397 | 1454 |
| 45 | 1159 | 2114 | 1816 | 1558 | 1707 | 1000 | 1590 | 1675 |
| 50 | 1411 | 2329 | 1931 | 1680 | 1778 | 1217 | 1614 | 1733 |
| 55 | 1715 | 1617 | 2070 | 1826 | 1864 | 1480 | 1644 | 1804 |
| 60 | 2087 | 1966 | 2240 | 2006 | 2051 | 1801 | 1680 | 1890 |
| 65 | 2539 | 2393 | 2446 | 2223 | 2279 | 2191 | 2045 | 1995 |
| 70 | 3090 | 2911 | 2697 | 2489 | 2556 | 2666 | 2486 | 2428 |
| 75 | 3759 | 3542 | 3002 | 2811 | 2893 | 3243 | 3026 | 2953 |
| 80 | 4574 | 4309 | 3373 | 3203 | 3303 | 3946 | 3681 | 3593 |
| 85 | 5565 | 5243 | 3825 | 3681 | 3802 | 4801 | 4479 | 4371 |
| 90 | | | 4374 | 4261 | 4409 | | | |
| 95 | | | 5044 | 4968 | 5148 | | | |

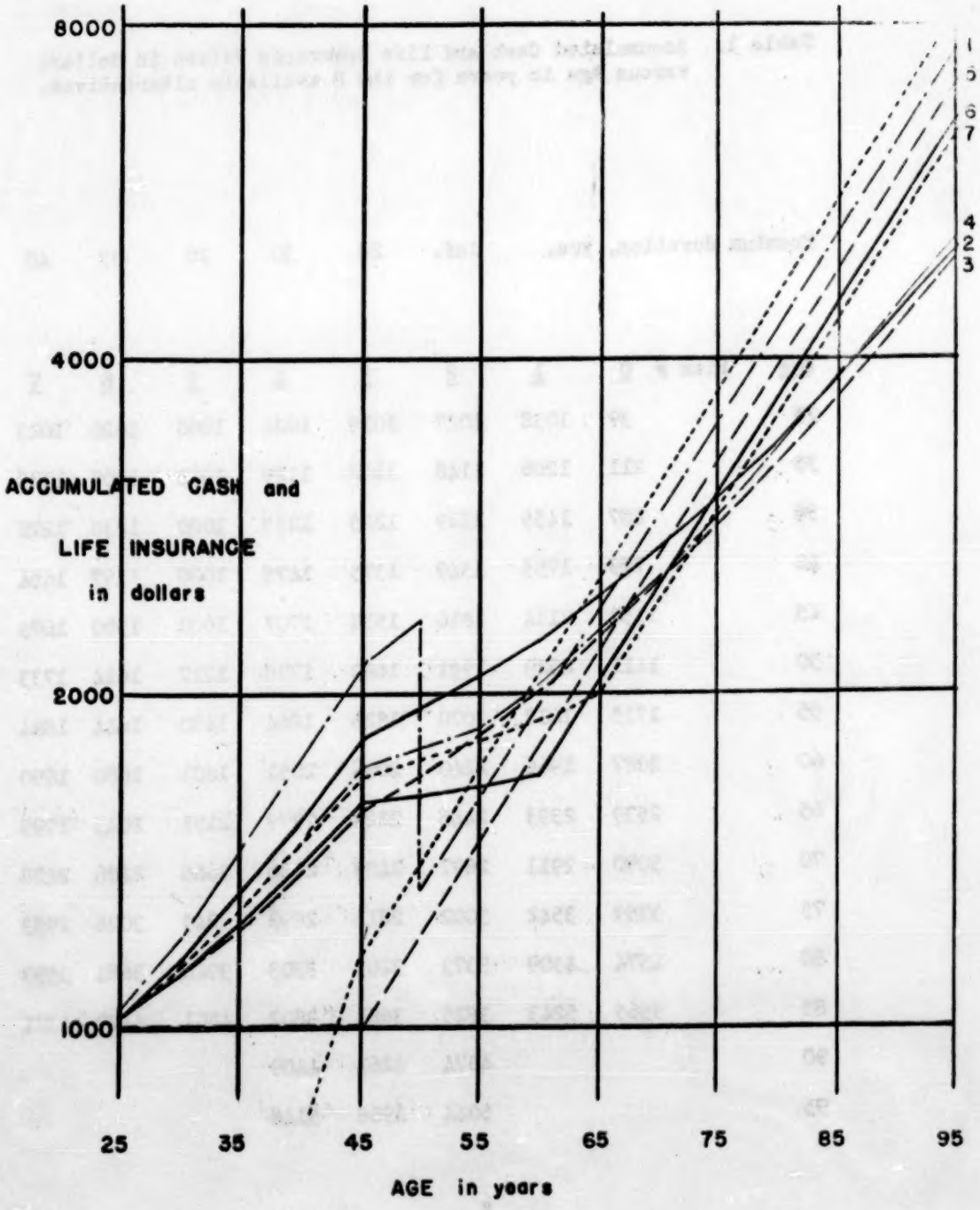


FIGURE 1 Comparison of values for various policies vs attained age

the insurance and accumulated fund respectively, hence represent less desirable sub-alternatives of those already considered. This will be true whenever the selected rate of return on the invested cash is greater than the return used by the insuring agency in its table compilation (generally 2½% to 3%).

The assumed age makes little difference in the comparison. The assumed rate of return can make considerable difference; e.g., increasing this rate would make the lower cost alternatives, 0 and 1, even more attractive.

As stated earlier, a more rational basis for selection has been the objective. The final selection by an individual policy-holder is still dependent upon his personal objectives. The analysis has clarified his selection by illustrating that certain alternatives under the assumed conditions are never advantageous (for example, alternative 5 is never as good as alternative 1, and alternative 3 is never as good as either alternative 2 or 4). Further, observation readily identifies the real advantages of the alternatives as well as the age brackets over which they occur.

* * *
*

Cutting across major technical professions comes . . .

## A NEW SCIENCE: COST ENGINEERING

For readers interested in cost engineering, we present the following statement concerning activities of the American Association of Cost Engineers. For the preparation of the statement, we are indebted to Thomas H. Arnold, Jr., of that organization.

The Editor

On a warm June Saturday in 1956, 60 engineers from all parts of the United States and Canada met at Durham, New Hampshire, to organize the American Association of Cost Engineers.

Upon returning to their offices the following Monday morning, many of these men were called upon by their associates to answer such questions as:

"How come you left here last week as an estimator and came back as a cost engineer?" Or,

"Just what is a cost engineer, anyway?"

The last question was the easiest to answer, as the new group had defined "cost engineering" in its constitution: "Cost Engineering is the application of scientific principles and techniques to problems of cost estimation, cost control and profitability."

Cost engineering thus cuts across the established major branches of engineering, such as civil and chemical engineering. But is it a new profession, or is it just another name for a function performed by engineers all the time?

In one sense, there is nothing new about cost engineering. All formal definitions of the engineering profession emphasize the

importance of economics. And a timeworn popular definition suggests that an engineer is a man who can do for one dollar what any fool could do for two dollars. The emphasis on economics, however, has traditionally been placedon capital costs because of the engineer's primary role in the design and construction functions. The contractor with the sharpest design and estimating staff is most likely to get the contract and earn a profit. The customer's project engineer or consultant analyzes each bid carefully to make sure of getting the best buy.

It has been only in recent years that the engineer has become intimately involved in the economic problems of production and research. In simpler times, accountants kept cost records, scientists chose their own research objectives, and owner-managers made the decisions as to what products to make and what facilities to build. Most engineers working in these areas concerned themselves with technical problems, often because management excluded them from the economic sphere.

Technology today has so permeated all of industry that many economic decisions affecting production and research cannot be intelligently reached without the participation of the engineer. Thus has arisen the function which is coming to be known as cost engineering. The cost engineer utilizes his technical background to attack problems combining technology, cost and profitability. This is especially true in the field of industrial research. The manufacturing industries in the United States spent nearly as much for research and development in 1958 as they did for new plants and equipment. To get maximum value for this expenditure,

the potential economic benefit of any research program must be assessed before it is begun and at frequent intervals throughout the program. Cost engineering is making a major contribution here.

Most cost engineers have arrived at their present positions without benefit of formal training in cost accounting, engineering economics, etc. Even those with previous training in those subjects have found that such training was inadequate. It was only natural that these engineers should seek the assistance of others faced with similar problems. The American Association of Cost Engineers provides an opportunity for these engineers to exchange ideas, develop new theories and techniques, set up standard terminology and codes, encourage cost engineering education and in other ways to advance the art and science of cost engineering.

In its first two and one-half years of existence, the association has grown to a membership of more than 600. Three national technical meetings have been held, in 1957 at Durham, N.H., in 1958 at Cleveland, Ohio, and in 1959 (June 24-26th) at Pittsburgh, Pa. National study committees are already working in such areas as terminology standards, cost indexes and cost records. Volume 1, Number 2 of the AACE Bulletin has just been published. Seven regional sections of the AACE are engaged in year-round activity.

Engineers interested in the aims and objectives of the AACE are invited to write for further information to: Edward D. Shanken, Executive Secretary, American Association of Cost Engineers, Durham, N.H.

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Review Article

# RECENT WORKS ON WATER RESOURCE EVALUATION *

Construction of large-scale multiple-purpose water works in the United States assumed the proportions of a program during the depressed 1930s. Typically, analysis of the problem followed actual development; it did not accompany or lead it. Two major statements on the economics of water resource evaluation appeared in 1950: (1) the now familiar "green book" of the FIARBC, Subcommittee on Benefits and Costs, and (2) Report of the President's Water Resources Policy Commission, "A Water Policy for the American People" (1950), Volume 1.

Increasing concern with water as a problem was manifested by the considerable literature that followed. The three works under review are, however, the first attempts at comprehensive treatment of the subject since 1950. They have important common ingredients of method, philosophy, and policy implications. While all take the theory of the firm - private market pricing and related welfare economics - as their point of departure and general

* Literature cited:

OTTO ECKSTEIN: Water Resource Development - The Economics of Project Evaluation. Harvard University Press, Cambridge, Mass., 1958. 300 pp. $6.50

JOHN V. KRUTILLA & OTTO ECKSTEIN: Multiple Purpose River Development - Studies in Applied Economic Analysis. Johns Hopkins Press, Baltimore, Md., 1958. 301 pp. $4.50

ROLAND N. McKEAN: Efficiency in Government Through Systems Analysis with Emphasis on Water Resources Development. John Wiley & Sons, Inc., New York, 1958. 336 pp. $8.00

frame of reference, McKean emphasizes the problem of efficiency in governmental decision-making. Though considerations of public welfare and the function of government are included, the bulk and weight of the analyses rest on such measurable private market criteria as electric power output and interest rates. Each book contains significant elements of theory (analysis) and illustrative material.

McKean's discussion of improved efficiency in water resource development is the basis for extending similar analytical concepts to public expenditures in general. He emphasizes the problem of suboptimization, that is, acceptance of "second-best" decisions as unavoidable within the constraint of budget limits, if problems are to be subdivided into manageable units. This problem may be met by preparing a series of proposals which reflect alternate assumptions concerning project components and valuation bases (e.g., discount rates). Such difficult problems in benefit-cost analysis as spillover effects (external economies), over-counting, and the valuation of benefits, are analyzed and then illustrated in two case studies: the Green River Watershed of Kentucky and Tennessee, and the Santa Maria Project in California.

While all three works concentrate on greater efficiency under existing arrangements, Eckstein, and especially Eckstein and Krutilla, give somewhat more attention to institutional issues. Eckstein's treatment of water resource evaluation questions is most comprehensive. His critical contributions to benefit-cost analysis include consideration of the following specific problems: economic justification versus evaluation; benefit-cost ratios versus the average

rate of return; benefit-cost ratios (b/c) versus excess of benefits over costs (b-c); adjustment for risk in selection of an appropriate interest rate; and issues in allocation of joint costs. In Chapters 5-8 the concepts and issues discussed are applied to the specific problems of flood control, navigation, irrigation, and electric power.

In Krutilla and Eckstein both the efficiency and income distribution effects of water resource development are considered. Their main contribution is in the latter area. In all three volumes considerable attention is given to the problem of time; specifically, determination of the most appropriate discount rate and time period for particular water projects or programs. In Krutilla and Eckstein this is discussed in the context of the redistribution effects of public works. (The analysis here, perhaps intuitively, responds to a suggestion in McKean, p. 132.) To ascertain the redistribution effects of public works, they make an estimate of the "social cost of Federal financing". They ask what is the amount by which the basic cost of Federal financing (e.g., the interest rate on government bonds) should be augmented to allow for the taxpayers "opportunity cost" of foregoing consumption or investment in order to pay the taxes that finance the project.

Two models are presented to illustrate the redistribution effects of alternative tax programs which (A) stimulate consumption and (B) stimulate investment. The authors conclude that Federal water resource projects should carry an interest rate of 5% to 6% if they are to cover the full social cost of

federal financing. Three case studies are presented. In the first two the efficiency criteria and the public versus private development controversy are illustrated by the Hell's Canyon Project in Idaho and the Alabama-Coosa River System. In the third, the redistribution analysis is extended in a hypothetical development of the Klamath River in Oregon.

All three books are the product of careful, thorough scholarship. They constitute together and apart the best statements of the problem to date. Since a very able review of the details of their analysis is available (American Economic Review, March 1959, pp. 96-111) comment here will be limited almost entirely to a critique of what these authors did not say. What they do not do is duly noted by each writer; however, the generally high quality of what they have done may easily lead the nonspecialist to feel that much more is being contributed than is actually the case.

It is felt that these works are more in the nature of terminal statements of rather well recognized issues than of path-breaking efforts that provide new insights into the problem. They provide important refinement in evaluation of quantifiable public expenditures. The relevance of their work, however, is severely circumscribed by the requisite of measurability and by assumptions such as full employment. While their analyses (particularly McKean's) are oriented to the prospect of improved efficiency of all public expenditures, application of their work admittedly becomes increasingly tenuous with respect to relatively non-quantifiable public expenditures.

In addition, the efficiency criteria developed do not clearly

distinguish between the problem of efficiency within an existing program or organization and the policy problem of efficiency between alternative programs. Their contributions could lead generally to more efficient administration in the sense of scientific management. However, in areas of public expenditure having no direct economic justification (e.g., the military or recreation) their efficiency criteria simply will not join with the basic allocation decision.

Such limitations are recognized by Krutilla and Eckstein in their statements concerning the need for discovery and application of "higher criteria" (in contrast to direct, short-run efficiency or income distribution goals). The importance of finding such "higher criteria" is related to the rate of increase and internal composition of the public sector of our society. Improvement of present benefit-cost analysis, which essentially applies private market criteria to public expenditures, may well yield progressively smaller returns over time. More important, since the goals of public functions are in most cases not the same as for private, criteria oriented essentially to the latter may be largely irrelevant for public welfare judgments.

Warren S. Gramm

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Review Article

# THE INVESTMENT DECISION *

The reviewer considers this to be an important book which should be read. The few critical comments which will appear below will not, it is hoped, discourage any potential reader. For although a great deal of work has been done in recent years to tell businessmen and political leaders how they ought to plan their investments, there remains the difficulty that those who are doing the investing are sometimes unaware of their ignorance. They proceed as best they know how, never knowing how wrong they are, and the country's economy somehow survives.

Meyer and Kuh were dissatisfied with the empirical bases of the existing theories of investment, and felt that it was time that some attention be devoted to a study of how firms DO invest. The product of their work is a book of 284 pages, of which about one-fourth is statistical appendices containing details of their analysis.

The study leans heavily on statistical techniques, primarily regression and correlation analysis, for reducing large quantities of data. Discussion of the statistical aspects of the analysis frequently crops up in the middle of more general discussion. This may be disconcerting to the reader who is not fully at ease with elaborate statistical techniques, but he should keep

* JOHN R. MEYER & EDWIN KUH: The Investment Decision. An Empirical Study. Harvard University Press, Cambridge, Mass., 1957. $6.00

going. Skipping over these sections will not significantly impair his understanding of what it is that Meyer and Kuh are saying.

Statistical tools are vital to such a study. The original sample consisted of some 750 firms, with more than 20 values recorded for each firm over a five year period (1946 through 1950). The number of variables was finally reduced to nine:

1) Investment
2) Sales
3) Net Profits
4) Depreciation Expense
5) Product of Current Sales Times the 1946 to 1949 Minimum Gross Fixed Assets to Sales Ratio
6) Change in Sales
7) Depreciation Reserves
8) Net Quick Liquidity
9) Dividends to Net Profit Ratio

It is notable that the authors emphasize the short time period and the large number of firms in their study. The major complaint in time series analysis is the lack of sufficient observations. The authors feel that the large number of firms offsets this disadvantage and at the same time makes the investigation of certain time factors more feasible, since the addition of one year of new data and the dropping of the oldest represents a replacement of 20% of the data and makes detection of even modest time effects likely.

The authors have recognized, of course, that in such an investigation they are faced with certain limitations:

(1) They are dealing with firms, not aggregates.

(2) They restrict the study to nine manufacturing industries.

(3) The results are applicable only to contemporary United States industry.

(4) It is assumed that decisions are based on observable phenomena.

(5) The emphasis is on short-run factors.

Of these, the last is the most serious, since it minimizes the significance of technological change. The fourth will be considered by some to be a serious drawback, omitting as it does any consideration of psychological theories of investment behavior.

Certain hypotheses are to be tested in the study. They are the ones which logically arise from the major theories of investment. The marginal theory says that investment is a function of the cost of capital equipment and the interest rate. It has long been recognized that such a view has some empirical failings. The interest is seldom a decisive factor, and the theory itself assumes away many factors which are important. The current trend in this field is to treat the decision criterion as utility maximization, rather than simple profit. The idea is nice, but difficult to make work. It usually leads to prescriptive rules of behavior in specific problems.

The acceleration principle asserts that change in capital stock depends on the rate of change of output. The weakness of the theory is that it is mechanistic; but it is easily tested. The practical problem is in the defining of what is to be meant by "change in output".

From a number of empirical studies which have already been made, come some generalizations about investment decisions. Three factors seem to be dominant in these: 1) internal liquidity considerations; 2) a strong preference for internal financing; 3) the

importance to the businessman of "trade position".

When compared with the results of the work of Meyer and Kuh the classical theories of investment come off a poor second. The influence of interest, so important to the marginal theory, is negligible. Instead, a factor which is rarely considered, stock price, is closely related. However, it is not possible to say which is the cause and which the effect.

The traditional view has held that in firms where investment has been low, and hence capital stock is old, there will be greater replacement investment, either gradually or lumpily. This is the so-called "echo effect". Meyer and Kuh find something quite different, which they call the "senility effect". The firms which have old equipment and low investment rates will, in general, continue so. This means a process of decline and decay for most firms and may be the ultimate of fiscal conservatism in management of the firm.

As was mentioned earlier, one of the major limitations of the study was the minimizing of technological change. But to the extent that the acceleration principle is observable here, it holds, subject to one qualification which has been encountered by everyone with a good idea: when funds are in short supply, the availability of money determines the fate of projects.

The problem of growth and liquidity restraints has important political implications in this country. Contrary to the views often expressed in political forums, small firms in general grow at internal rates which are as good as those of the large firms. They exhibit a greater sensitivity to liquidity factors, which

may mean that they have more problems in getting funds when the economy is operating at a slower pace.

In the last chapter, Meyer and Kuh advance their own "Residual Funds Theory of Investment". The essence of the theory is that, in the short-run, investment is determined by the excess of the net flow of funds over the planned dividend payout. Technological factors will dictate the long-run investment in the vital firm, and the details of the short-run will be influenced by attitudes about trade position and the peculiarities of the firm's market.

All of this represents the investment behavior of the firm as being a determined sort of matter. The implication seems to be that all of these factors are busy at work, that the manager of the firm, either consciously or otherwise, evaluates them and then makes his decision to invest. A somewhat different view is implied in H. A. Simon's theories about managerial behavior. According to Simon, the manager will strive to achieve not the maximum, but a satisfactory, level of activity. If the two coincide, so much the better, but if the satisfactory level is reached first, there will be no further efforts to advance; rather, that position will be exploited.

Meyer and Kuh offer a world in which the manager would appear to have no control. He is not to be allowed to manipulate his environment. Simon's manager may only "satisfice",[1] but at least he is a willful individual who is not afraid to try to change his

[1] James G. March & Herbert A. Simon: Organizations. John Wiley & Sons, Inc., New York. 1958.

environment. This reviewer is of the opinion that there is a great deal more attempted control over the variables that Meyer and Kuh show are correlated with investment, than would be guessed from their discussion. Within reasonable limits, managers can set down objectives for their sales volume, for their production costs, for their inventories. They can, through the manipulation of the accounting rituals, change the depreciation charges. And from all this, they can set objectives for their profits and for the flow of funds. Indeed, it would be a foolish firm which discarded its cash budget as an item in planning its operations.

Managers make the decisions to invest on the basis of certain factors. Meyer and Kuh have given us some extremely illuminating information on what some of these factors are, and what some of them are not. But the manager who is seeking advice on how he SHOULD invest is only a little better off: he now has some idea about what others actually do.

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THE ENGINEERING ECONOMIST

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